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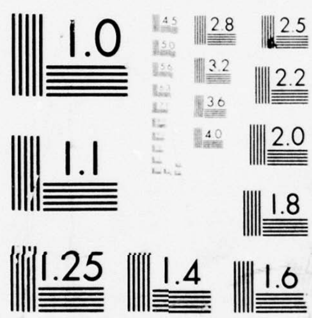
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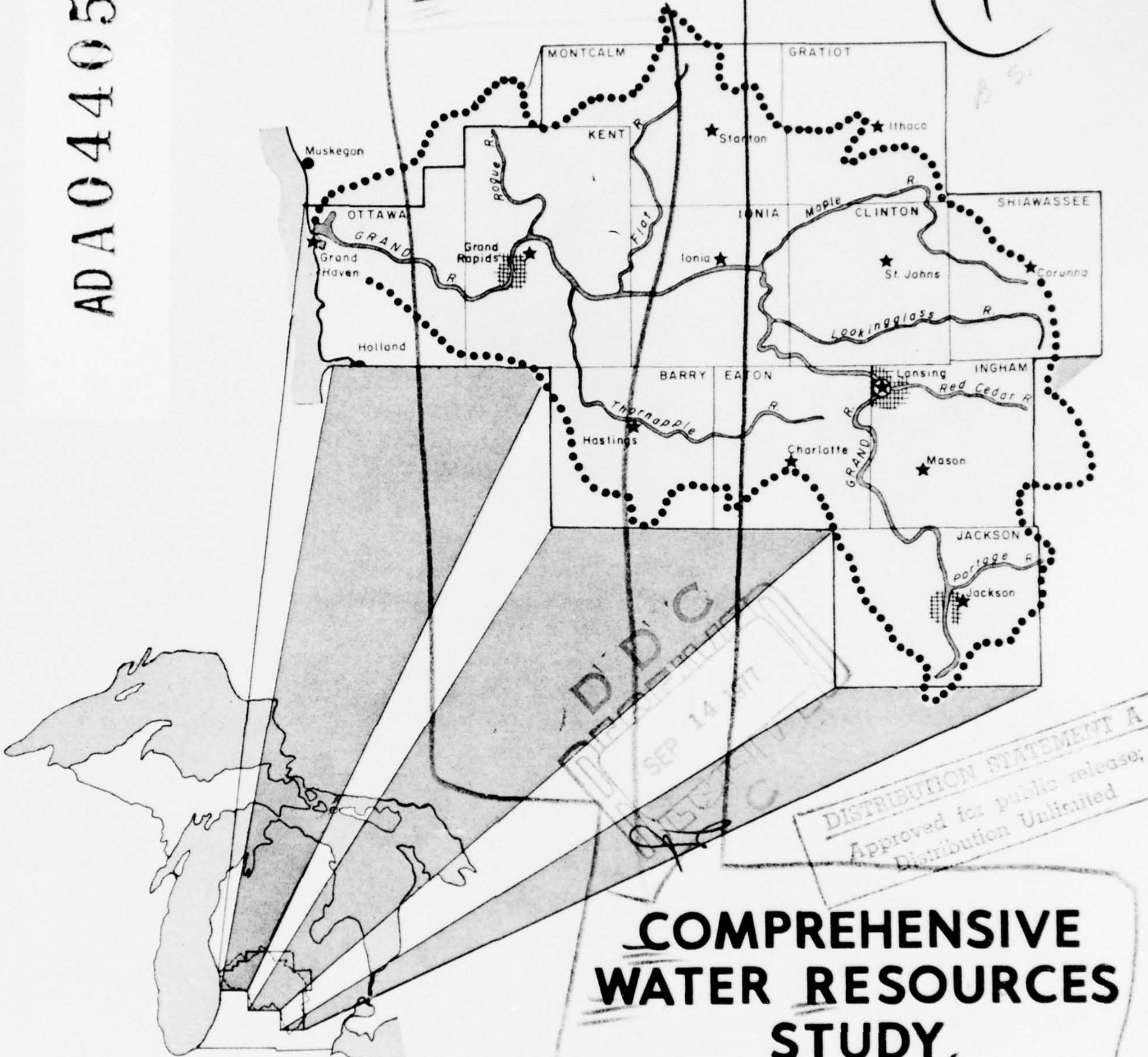

COMPREHENSIVE WATER RESOURCES STUDY

VOLUME VI

APPENDIX H - FLOOD CONTROL
APPENDIX I - NAVIGATION

Prepared Under Supervision of the
GRAND RIVER BASIN COORDINATING COMMITTEE
Chairmanship: U. S. Army Engineer District, Detroit

May 1970

APPENDIX H

FLOOD CONTROL

COMPREHENSIVE PLANNING STUDY
OF THE
GRAND RIVER BASIN, MICHIGAN

Prepared by the
U.S. Army Engineer District, Detroit
Corps of Engineers
Detroit, Michigan

1969

APPENDIX H
FLOOD CONTROL

COMPREHENSIVE PLANNING STUDY
OF THE
GRAND RIVER BASIN, MICHIGAN

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SECTION I

INTRODUCTION

1. DESCRIPTION. The Grand River basin has a drainage area of 5,572 square miles, is generally oval in shape, is 135 miles long, and has a maximum width of 70 miles. Plate H-1 shows the watershed boundary, the location of the basin within the State of Michigan, and the localities with flood problems. The Grand River is 260 miles long and drops 460 feet. It has a steep slope from its source to the vicinity of Ionia, over half its length, but has a very flat slope from Ionia to Lake Michigan. The surface deposits of the Grand River basin are permeable glacial drift of great depth so that the major part of precipitation run-off ordinarily reaches the stream by precolation. Therefore, low flows are high and well-sustained in comparison with streams in other sections of the country.

2. Riverbed widths of the Grand River vary from over 500 feet near its mouth to under 100 feet downstream of Jackson. Water depths vary considerably during high, low, and normal flows. Plate H-2 shows these variations during high flows in the Grand River and its major tributaries. During flood stages, channel depth may increase from 6 to 10 feet before the immediate banks are overtopped. Most of the stream banks retain the flow of only annual frequency magnitude. The river valley below Grand Rapids is flooded to a width of 1,000 to 4,000 feet during extreme floods, which rise 12 to 18 feet above low water at Grand Rapids. The flood plain between Grand Rapids and Ionia is one-third to three-fourths of a mile wide. The flood level for extreme floods is approximately 20 feet above low-water level. Above Ionia the capacity of the channel for discharging flood waters is much greater, due to steeper slopes. Flood profiles for extreme floods are from 11 to 15 feet above low water. Flood plains there vary from 500 feet to a half mile in width as the channel meanders across the valley. Above Lansing, the river winds through an irregular valley from 200 feet to one-quarter mile in width, traversing a distance by river thread of 65 miles in an airline distance of about 35 miles. Extreme flood stage is 6 to 10 feet above low water, but the flooded area is not extensive. At and above Jackson, practically no troubles arise from floods, which are partly controlled by the operation of the Jackson and the Michigan Center dams.

3. The Grand River's tributaries, except the Maple River, have relatively steep slopes, from 3.1 to 10.6 feet per mile, and do not cause serious flood damage except for the lower few miles, which are flooded by backwater from the main stream. Flood stages on the Lookingglass, Flat, and Thornapple Rivers are from 5 to 10 feet above low water. Much of the fall on the latter two rivers has been developed for power;

the pools inundate most of the flood plains. The Maple River has an average fall of 1.6 feet per mile and flows through the flat summit swamps on the divide between the Lake Michigan and Lake Huron watersheds.

4. GEOGRAPHIC LIMITS. This flood control study is in two parts: first, main stem and principal tributaries; second, upstream watershed areas. The upstream watershed flood control studies are described in detail in Appendix M, Agriculture, of this report. The Department of Agriculture's Soil Conservation Service and the Corps of Engineers agreed to define these areas to avoid duplication of work. The study is broken down by reach as follows:

REACH DESCRIPTION

Corps of Engineers

a. Grand River, main stem up to Jackson (Mile 0 to 219)

b. Red Cedar River, main stem up to Williamston (Mile 0 to 22)

c. Lookingglass River, main stem up to DeWitt (Mile 0 to 25)

d. Stony Creek, up to Wright Road (Mile 0 to 12)

e. Maple River, up to US-27 Federal Highway (Mile 0 to 23)

f. Flat River, main stem (all)

g. Thornapple River, main stem (all)

h. Rogue River, main stem (all)

Soil Conservation Service

a. Portage River - main stem (all)

b. All upstream areas not specified for study by the Corps of Engineers

5. FLOOD HISTORY. Most of the floods in the Grand River basin occur in the late winter and early spring months of February through May, and result from rain falling on frozen snow-covered or saturated ground. These floods are normally accompanied by warming temperatures which frequently melt channel ice before the ice is out of the channel thus reducing the river's capacity to discharge storm runoff. The ice breaks into large sheets and piles up in jams at bridges, restrictive channel areas, and other river structures, thus aggravating the flood situation and endangering downstream structures. Maximum unit discharge for the Grand River range from 11 to 20 cfsm (cubic feet per second per square mile of drainage area). These rates are higher than peak rates for adjacent drainage areas of comparable size in southern Michigan. Floods are also experienced during the early summer months of June and July. These floods result from very intense rainfalls; however, the limited aerial coverage of these

storms and the increased channel capacities of the downstream channels prevent widespread flood conditions from occurring due to these storms. Urban and main stem agricultural average annual damages experienced within the Basin are $990,700 and $26,490 respectively. Pertinent flood damage data within the Basin are presented in Table H-1. The major flood of record on the Grand River occurred in March 1904. It was caused by high temperatures. Maximum discharges of 54,000 cfs at Grand Rapids and 24,500 cfs at Lansing were recorded for this flood. Other major floods of record of slightly less magnitude were experienced along the main stem channel in March 1948, April 1947, March 1918, March 1908 and June 1905. In addition, water surface elevations above flood stages along the main stem were reached twice in 1949 and three times in the opening of 1950. These floods resulted from separate snow melts and high intensity rainfalls. Pertinent flood data for major floods experienced at Grand Rapids, Lansing, and East Lansing, which comprise about 70 percent of the Basin's total average annual damages, are presented in Table H-2.

TABLE H-1

SUMMARY OF FLOOD DAMAGES
GRAND RIVER BASIN

Average Annual Damages

	Grand River	Index Pt.	Zero Damage Elevation	River mile	River Reach	Avg. Ann. Damages
1.	Grandville	28th St. Bridge	594.6	34.6	34.0 to 37.0	$109,800
2.	Grand Rapids	Fulton St. Br.	603.7	40.8	37.2 to 45.5	390,000
	Comstock Park(Agri)	N. Park Br.		45.1	43.0 to 53.4	2,530
3.	Plainfield Twp.	N. Park Br.	612.0	45.1	45.5 to 51.3	48,500
4.	Ada	M-21 Br.	619.0	61.9	61.3 to 62.3	3,480
	Ada (Agri)	"		"	53.4 to 56.0	4,080
5.	Lowell	M-91 Br.	622.5	70.0	69.6 to 71.0	54,200
	Lowell (Agri)	"		"	66.0 to 78.0	4,450
6.	Saranac	Bridge St.		78.0	77.5 to 78.2	No Est.
7.	Ionia	M-66 Br.	629.0	87.5	86.9 to 89.2	50,000
	Ionia (Agri)	"		"	78.0 to 97.8	9,900
8.	Lyons	Lyons Dam	648.6	96.0	95.3 to 96.2	2,730
9.	Portland	Kent St. Br.		115.0	112.2 to 113.5	No Est.
	Portland (Agri)	"		"	97.8 to 127.0	1,250
10.	Grand Ledge	W.B. Gage		140.0	139.0 to 142.0	No Est.
	Grand Ledge (Agri)	"		"	127.0 to 140.0	160
11.	Lansing	N. Grand River Ave. Br.	819.0	148.7	150.5 to 158.0	54,300
	Lansing (Agri)	"		152.3	146.0 to 158.6	110
12.	Dimondale	Bridge St. Br.		164.8	164.4 to 165.1	No Est.
	Dimondale (Agri)	"		"	158.6 to 171.4	500
13.	Eaton Rapids	Hamlin St. Br.	859.5	180.0	180.0 to 181.5	14,290
	Eaton Rapids (Agri)	"		"	171.4 to 216.0	2,050
14.	Jackson	Sew. Treat. Pl.		216.0	217.0 to 219.5	No Est.
Summary					34.0 to 216.0	$752,330
	Red Cedar River					
15.	East Lansing	Farm Lane Br.	832.2	6.5	3.3 to 7.2	$241,600
	East Lansing (Agri)	Williamston Dam		21.0	0 to 21.0	1,460
Summary					0 to 21.0	$243,060
	Sycamore Creek					
16.	Mason				12.7 to 14.6	$ 21,800
					BASIN TOTAL	$1,017,190

TABLE H-1 (Cont'd)

Average Annual Damages

	Index Pt.	Zero Damage Elevation	River mile	River Reach	Avg.Ann. Damages
Areas of Other Limited Flood Damage (No Estimates Made)					
Maple River					
17. Muir				0.6 to 0.9	
18. Maple River				about 19	
19. Ovid				about 54	
Red Cedar River					
20. Okemos				9.5 to 10.9	
21. Williamston				20.2 to 22.2	
22. Fowlerville				about 33	
Thornapple River					
23. Hastings				about 42	

TABLE H-2

DATA FOR GRAND RIVER BASIN MAJOR FLOODS

	U. S. Geological Survey Gage Location		
	E. Lansing (Red Cedar River)	Lansing (Grand River)	Grand Rapids (Grand River)
Zero Damage Elevation (feet)	832.0	819.0	603.7
Related Discharge (cfs)	2,500	10,000	27,000
1904 Flood			
Stage (feet)	837.8	825.2	610.0
Discharge (cfs)	8,000	24,500	54,000
Volume (inches)	3.53	3.50	2.04
Duration* (days)	6	6	10
1905 Flood			
Stage (feet)	834.7	820.3	609.4
Discharge (cfs)	4,900	12,800	50,200
Volume (inches)	1.83	1.45	2.04
Duration (days)	4	4	7
1947 Flood			
Stage (feet)	835.9	822.5	606.8
Discharge (cfs)	4,900	16,400	38,600
Volume (inches)	1.54	1.38	1.33
Duration (days)	4	3	5
1948 Flood			
Stage (feet)	834.9	820.0	607.6
Discharge (cfs)	4,960	12,000	42,200
Volume (inches)	1.32	1.08	1.46
Duration (days)	3	1	5

*Length of time above flood stage

6. PAST DEVELOPMENTS. No Federal flood control projects have been constructed in the Grand River basin. Following the March 1904 flood, the city of Grand Rapids expended approximately $1,000,000 for the construction of flood retaining walls and levees, with accompanying interior drainage along the banks of the Grand River within the city limits. These walls were designed with a two-foot freeboard allowance over the stages reached during the 1904 flood. Their effectiveness is evidenced by the fact that flooding damage since their construction has been confined to the southwestern section of the city of Grand Rapids which is not protected by the walls. However, the 1948 flood crested within two feet of the top of these walls. The downtown area of Grand Rapids extends along the left bank of the River immediately adjacent to this flood wall. Small service businesses, large and small industries, and residential areas are located on the right bank of the river. The streets on both sides of the river in this section are several feet below the top of the floodwall. Because of channel silting and encroachment of the walls into the natural flood plain, a flood of the 1904 magnitude would probably overtop the flood walls.

7. The city of Jackson modified the Grand River channel by encasing the river in a concrete conduit placed on the existing riverbed through the central business district and by widening and straightening the river channel from Jackson Road to Berry Road, about eight miles north of Jackson. Most of the concrete conduit is exposed, except for a small section buried under buildings along both sides of Michigan Avenue. No significant flood damage has occurred since this improvement.

8. No other flood control projects of consequence have been constructed by other Basin communities. Lowhead power dams have been constructed and maintained, but the storage capacity of these structures is so limited that they have little effect on flood conditions downstream.

9. GUIDELINES FOR DAMAGE ESTIMATES AND PROJECT FIRST COSTS

a. Damage estimates

(1) Residential flood damages. Residential flood damages in the Basin have been estimated by synthetic methods for grounds and for buildings and their contents. The synthetic curves were originally prepared by the St. Paul District, Corps of Engineers, and are based upon market values of dwellings and depths of flooding. Tables H-3 and H-4 presented below, developed from the St. Paul District data, show estimated flood damages that would occur in typical houses having various market values. As an example, a $10,000 house with a basement is assumed to have a radio, record player, sewing machine and television set on the first floor, and a furnace, washing machine, dryer, deep freezer, work bench, and tools in the basement. The market value (say $10,000) does not include the land value.

TABLE H-3
TYPICAL FLOOD DAMAGE ESTIMATES
TO RESIDENTIAL UNITS WITH BASEMENTS

Market Value Of Residences (dollars)	Basement Flooding		1st Floor Flooding*	
	Depth over Floor (feet)	Damages (dollars)	Depth over Floor (feet)	Damages (dollars)
	1.0	360	0.5	2,550
$ 8,000	3.0	580	1.0	3,020
	1.0	530	0.5	3,080
$10,000	3.0	810	1.0	3,700
	1.0	640	0.5	3,600
$12,000	3.0	980	1.0	4,300

* Includes full basement damages

TABLE H-4
TYPICAL FLOOD DAMAGE ESTIMATES
TO RESIDENTIAL UNITS WITHOUT BASEMENTS

Market Value of Residences (dollars)	1st Floor Flooding	
	Depth over Floor (feet)	Damages (dollars)
	0.5	2,000
$ 8,000	1.0	2,600
	0.5	2,320
$10,000	1.0	3,000
	0.5	2,650
$12,000	1.0	3,320

(2) Industrial and commercial flood damages. Industrial and commercial flood damages were computed from data obtained by random interview and on-the-spot inspections. Estimates include physical damage to buildings, grounds, equipment, and building contents; cost of flood fighting; loss of earnings; and increased costs of production.

(3) Flood profiles. Flood profiles were developed at each locality for two or more recorded or hypothetical floods. Flood outlines which show basement and overland flooding were drawn on area maps, using the profiles. Except where otherwise indicated, the maps show the major flood of record (the 1904 flood) for the urban damage centers. Also included is a summary sheet of flood damage estimates in the individual communities from the selected floods.

(4) Price index. Damage data are estimated in monetary values which are in accordance with the February 1960 Engineering News Record (ENR) Construction Cost Index.

(5) Level of development. The flood damage estimate summaries for the individual cities do not include either estimates of future damages due to economic growth or benefits that could accrue from the diminishing flood hazard due to a project. All estimates of flood damage were prepared for conditions and degree of development at the various damage centers during the year of 1965. However, damages are estimated at the 1960 ENR Index level, unless noted otherwise.

(6) Average annual damages. Average annual damages were computed using stage-damage, stage-discharge, and discharge-frequency relationships developed for the individual damage areas. (Figures 1 through 10).

b. Project first costs. Protection schemes were developed for each urban center where damages were significant and project costs were estimated. Included in each considered plan of improvement are all component parts of the project. Contingencies of 25 percent of the given Federal or non-Federal construction costs are included and identified in the estimates. The costs of engineering and design are identified, and are shown as 10 percent of the Federal or non-Federal construction costs (including contingencies). The costs of supervision and administration are 6.5 percent and 7.3 percent for Federal and non-Federal construction costs respectively (including contingencies and engineering and design). Estimates are based on experience and cost records of similar projects of comparable size.

(1) Price levels. February 1960 price levels were used for estimating all costs and benefits.

(2) Investment costs. For projects which would take more than two years to construct, the investment cost has been estimated as equal to the first cost plus interest on the first cost for half the construction period. Interest for construction periods of two years or less was disregarded.

(3) Interest rate. The interest rate used in studies of project investment, evaluation, allocation of costs, and cost sharing is 4-5/8 percent. (Recommended rate as of April 1969.)

(4) Annual cost. Annual costs were computed, including annual interest and amortization of the project investment over the estimated economic life of the project. Also included in the annual cost is the estimated allowance for operation and maintenance of the project and reserves for repair and replacement costs. The economic life or amortization period, used for evaluation purposes is 50 years or the physically useful life of the facilities, whichever is shorter.

SECTION II

URBAN FLOOD CONTROL STUDIES

10. GENERAL. Many of the Grand River basin's major urban areas are subject to periodic flooding. The urban areas subject to flooding within the Basin, listed in Table H-5, are located primarily along the main stem of the Grand River and along some of the major tributaries. The scope of study performed for each of these urban areas was based on the extent of damage potential that existed. The damage potential of each area was evaluated through field reconnaissance, contacts with local people, and available office data. Detailed studies indicated that damages would be significant. The scope established for these detailed studies is preliminary; however, enough detail is contained to estimate the economic feasibility of selected plans of improvement. These studies consisted of description and identification of the flood problem, and selection of several plans of improvement (such as local protection, area evacuation, and flood control reservoirs) to alleviate the flood problem. In addition, flood control plans were compared to each other to determine which of the plans would yield the greatest excess of benefits over costs. Pertinent flood data for areas for which detailed studies were made are presented in Table H-6.

TABLE H-5

URBAN DAMAGE CENTERS

City	River Reach (Miles from mouth)
Grand River	
1. Grandville	34.0 to 37.0
2. Grand Rapids	37.2 to 45.5
3. Plainfield Township	45.5 to 51.3
4. Ada	61.3 to 62.3
5. Lowell	69.6 to 71.0
6. Saranac	77.5 to 78.2
7. Ionia	86.9 to 89.2
8. Lyons	95.3 to 96.2
9. Portland	112.2 to 113.5
10. Grand Ledge	139.0 to 142.0
11. Lansing	150.5 to 158.0
12. Dimondale	164.4 to 165.1
13. Eaton Rapids	180.0 to 181.5
14. Jackson	217.0 to 219.5
Red Cedar River	
15. East Lansing	3.3 to 7.2
16. Okemos	9.5 to 10.9
17. Williamston	20.2 to 22.2
18. Fowlerville	about 33
Sycamore Creek	
19. Mason	12.7 to 14.6

TABLE H-5 (Cont'd)

City	River Reach (Miles from mouth)
Maple River	
20. Muir	0.6 to 0.9
21. Maple Rapids	about 19
22. Ovid	about 54
Thornapple River	
23. Hastings	about 42

TABLE H-6

MAJOR FLOOD DAMAGE CENTERS

Community	Upstream Drainage Area	RECORD FLOOD DATA Year	Stage (USGS)	Maximum Discharge	Average CFS/SM
Grandville	5,000	1904	605.4	54,000	10.8
Grand Rapids	4,900	1904	609.9	54,000	11.0
Plainfield Twp.	4,850	1904	617.1	54,000	11.2
Ada	4,000	1904	628.2	52,500	13.1
Lowell	3,640	1904	633.7	44,000	12.1
Ionia	2,840	1904	643.5	45,000	15.8
Lyons	1,777	1904	653.8	32,600	18.4
Lansing	1,230	1904	825.8	24,500	19.9
Eaton Rapids	661	1947	868.8	8,900	13.4
East Lansing*	355	1947	835.9	5,920	16.6

* East Lansing is on the Red Cedar River; all other communities listed are on the Grand River.

11. GRANDVILLE

a. Description of area. The city of Grandville is located on the main stem of the Grand River about six miles downstream of Grand Rapids. The city encloses about 7-3/4 square miles within its boundaries. About 5,000 square miles of the Grand River basin lie upstream of the city; thus, all major tributaries within the Basin contribute to Grand River discharges upstream of Grandville. Three small ditches drain into the Grand River within the Grandville city limits and comprise a drainage basin of about 130 square miles. In the immediate vicinity of Grandville, the topography ranges from an elevation of 590 feet along the flood plain to 800 feet in the nearby hills. Soils generally are typical glacial drift deposits. The fall of the Grand River through the city to Lake Michigan is about 17 feet in 34 miles and within the city limits the average depths are about eight to nine feet, with the water surface widths varying from 175 feet to 350 feet. During flood conditions, stages rise another six or seven feet, while water surface widths increase to about 550 feet without overflowing their banks. The maximum non-damage flow in the Grand River is about 15,500 cfs.

b. Flood problems. Virtually every year the city of Grandville suffers flood damages caused by the Grand River. Direct and indirect damages are caused to residences and commercial and industrial establishments. Floods have been experienced at Grandville in 40 of the 67 years of record from 1901 through 1967; eleven major floods having been experienced in this period. For the purposes of this report, a major flood at Grandville is taken to be a discharge in excess of 30,000 cfs. The most severe of the floods of record occurred in March 1904, when the river crested at an elevation of 605.4 feet (which is 10.8 feet above zero-damage elevation of 594.6 feet) with an estimated peak discharge of 54,000 cfs. During floods, overland and basement flood damages are common between Chicago Drive and the river. North of 28th Street, the area is relatively sparsely settled, but south of 28th Street there is a heavy concentration of residential, commercial, and industrial establishments. A recurrence of the 1904 flood stage would send flood waters over and to the south of Chicago Drive and basement flooding would penetrate southward from 28th Street and eastward from Buck Creek.

c. Average annual damage computations. The city of Grandville experiences flood damages of variable intensity almost every year. Damages have been computed for three floods of record: 1950, 1948, and 1904, and for a hypothetical flood of 75,000 cfs. Estimated tangible flood damages for the three recorded floods under 1961 conditions ranged from $103,000 for a recurrence of the 1950 flood stage to $783,000 for a recurrence of the 1904 flood stage. Relationships among flood stage, discharge, and damage are plotted in Figure H-1. Table H-7 contains a summary of the damage that would result from occurrence of a hypothetical flood and from recurrences of the 1904, 1948, and 1950 floods. The 1904 flood outline is shown on Plate H-3.

TABLE H-7

FLOOD DAMAGE SUMMARY - GRANDVILLE, MICHIGAN

RIVER: Grand
RIVER MILE: 34.6
INDEX POINT: 28th Street Bridge-Grand River

	Hypothetical flood	1904 flood	1948 flood	1950 flood
1. Flood stage (USGS elev)	609.1	605.4	602.7	599.0
2. Exceedence freq. (percent)	0.35	1.8	5.2	25.0
3. Discharge (cfs)	75,000	54,000	42,200	27,200
4. Computed residential damages				
a. Units	445	298	154	81
b. Damages	$443,000	$287,500	$118,000	$55,000
5. Computed commercial & industrial damages				
a. Units	121	105	90	28
b. Damages	$2,097,000	$495,500	$143,000	$48,000
6. Totals				
a. Units	566	403	244	109
b. Damages	$2,540,000	$783,000	$261,000	$103,000
7. Average annual damages (1961 price level)		$109,800		

d. Solutions considered

(1) Three methods of flood control protection were considered to alleviate the flood damage problem at Grandville: reservoirs, channel improvements, and construction of levees. Each of these solutions is described in the following paragraphs:

(a) Flood control reservoir studies indicate that this method of control at Grandville would not be economically feasible. An extensive network of reservoirs would be necessary to control the Basin runoff. The cost of reservoirs at these numerous sites prohibits this as an effective method of flood control.

(b) The channel slope from the problem area downstream to Lake Michigan is less than one foot per mile. Extremely large channel excavations would have to be made to produce an appreciable change in flood stages at Grandville. The cost of this excavation makes this method of flood control impractical.

(c) The construction of a levee system with interceptors and pumping facilities for interior drainage has been found to be the most practicable and justifiable method of effectively controlling flood problems and enhancing land values in the city of Grandville. The plan selected (Plate H-4) includes a levee on the right bank of Buck Creek from near Chestnut Avenue to the Interstate Highway I-96, which has since been redesignated as I-196. From this point a low levee and impermeable blanket would be placed on the river side of the existing Interstate Highway I-196 embankment from Buck Creek to 28th Street. A third section of levee would extend along the north side of 28th Street from Interstate Highway I-196 to the vicinity of Sanford Avenue and 28th Street. Some of the more important project features are:

1. The design water surface elevation of the levees is 608 feet.

2. The average height of the levee embankment is 12 feet.

3. The levee top width is 10 feet, and the sideslopes are 1 vertical on $2\frac{1}{2}$ or 3 horizontal.

4. The freeboard allowances range from 2 to 4 feet.

5. Closure structures are necessary at street crossings.

6. The gravity outlet and pumping station structure is located along Buck Creek between the C. & O. Railway and I-196.

e. Economic analysis. The cost summary shown in Table H-8 includes computations for relocations, levees, land acquisitions, and associated costs for the plan of protection at Grandville. Cost analysis was determined as follows:

	Federal	Non-Federal
Contingencies	25%	25%
E & D	10%	10%
S & A	6.5%	7.3%

Average annual charges for the proposed plan of protection are estimated to be \$79,900 for an interest rate of 4-5/8 percent plus amortization. Average annual tangible benefits to be derived from these works are estimated to be \$75,000. Hence the ratio of benefits to costs is 0.94.
B/C ratio of 1.2, $\frac{\$75,000}{\$60,300} = 1.2$
Based on price levels of 1961 and an interest rate of 2-5/8 percent.

f. Summary of Investigation. The city of Grandville is subject to flooding almost every year with average annual damages estimated to be \$109,800. Engineering studies indicate that a levee system would provide \$75,000 of average annual benefits for an average annual cost of \$79,000. Previous economic studies indicated a feasible project and resulted in an interim survey report for Grandville which recommends project authorization. As a result of a new interest rate of 4-5/8 percent the B/C ratio is now unfavorable. Further economic studies will not be undertaken and pre-construction planning will not be initiated. To date local interests have not indicated a willingness to fulfill the local cooperation requirements.

TABLE H-8

ESTIMATE OF COST - SUMMARY, GRANDVILLE (IN DOLLARS)
Price Levels of June, 1961

Item	Contract costs	Contingencies	Engineering & design *	Supervision & administration	Total
Federal Cost					
Railroad Relocations	4,100	1,025	520	370	6,015
Levees	831,500	207,900	103,940	74,320	1,217,660
Pump Stations	180,000	45,000	22,500	16,100	263,600
Total Federal Cost	1,015,600	253,925	126,960	90,790	1,487,275
Non-Federal Cost					
Lands	25,000	6,250	-	-	
Utility Relocations	20,000	5,000	2,500	2,000	
Total Non-Federal Cost	45,000	11,250	2,500	2,000	60,750
				Total First Cost	1,548,025

* Does not include an estimated $14,800 preauthorization charge.

12. GRAND RAPIDS

a. Description of the area

(1) The Grand River and its tributaries drain an area of about 5572 square miles of southern and central Michigan. About 4900 square miles of the drainage basin lie upstream from Grand Rapids, which is located in the reach from river mile 37.2 to 45.5. The seven major tributaries drain into the Grand River upstream of Grand Rapids. The U. S. Geological Survey (USGS) has maintained stream gaging stations at Grand Rapids from 1901 to 1905 and from 1930 to date. Stage records during the period 1905 to 1930 were obtained by the U. S. Weather Bureau. The USGS stream gaging station is currently located in NE ¼, Sec. 25, T7N, R12W, on the right bank 500 feet upstream from the bridge on Fulton Street, 1.7 miles upstream from Plaster Creek at river mile 41. Flood elevation of the March 28, 1904, flood was 608.2 feet at Pearl Street, where the stream gaging station was located at that time.

(2) Within the city limits of Grand Rapids are two creeks (See Plate H-5) that discharge into the Grand River. Plaster Creek, the larger, is 22.3 miles long, and drains an area of 45.5 square miles to the southeast of Grand Rapids. Indian Mill Creek is 9.7 miles long and drains 20 square miles northwest of Grand Rapids.

(3) The valley floor of the lower Grand River basin westward from Ionia is flat with a gently sloping gradient to Lake Michigan. In places, the flood plain may extend for an overall distance of one-half mile beyond the banks of the Grand River. Beyond the valley floor, which is one-half mile to eight miles broad, are rolling hills of glacially deposited sands and gravels. Near Grand Rapids, elevations range from 590 feet in the flood plain to 840 feet in the nearby hills. The maximum relief in the city is 210 feet, from a low elevation of 590 feet at the river's banks to a maximum elevation of 800 feet on the west side just south of Reeds Lake. All elevations established in connection with these studies have been referred to USGS datum and mean sea level.

(4) The Grand River is approximately 500 to 600 feet wide as it passes through the city. Stream-bank elevations are about 610 feet in the northern portion of the city and about 595 feet in the southwestern portion of the city. After the record flood of 1904, the city of Grand Rapids built floodwalls and levees with interior drainage works for protection of the city. The floodwalls and levees were constructed to exceed the 1904 flood profile by two feet of freeboard. To date the floodwalls have provided satisfactory control against floods and prevented serious damage.

(5) The Grand Rapids sewer system is mostly separate storm and sanitary sewers except for the older parts of the city, which have combined storm and sanitary sewers. The city is now converting the combined sewers to a separate sewer system. Where the sewers are separate, the storm sewer

outlets empty either directly into the Grand River or into Plaster Creek, Indian Mill Creek, or Lamberton Creek. Most of the storm sewer outlets emptying into the Grand River are equipped with flap gates or slide gates. Most of the sanitary sewers from the outlying areas connect into the combined system where the sewage is conveyed by gravity to the Market Street Pumping Station. From here, the sewage is pumped to the nearby sewage treatment plant. The Market Street Pumping Station handles 75 percent of the area's sewage; the rest goes directly to the plant from the southeastern part of the city by gravity flow. Often, after a storm, the capacity of the sewage treatment plant is exceeded, and the excess amount is discharged directly into the river at the Market Street Pumping Station. On rare occasions, it is necessary to divert above-normal sanitary sewage flows directly into the Grand River. When the Grand River stage exceeds 601.3 feet, the river backs up into the sewage treatment plant effluent (outlet) pipe. When this happens the sewage treatment plant halts all treatment and diverts all sewage flow to the Market Street Pumping Station where it is pumped directly into the Grand River. The Market Street Pumping Station has two pump houses, the original facility built in 1911 and the newer one built in 1927. The older pump house was part of the original flood control project of floodwalls and levees constructed in 1911 to prevent a recurrence of the disastrous 1904 and 1905 floods. It has four 42-mgd pumps for diverting excess storm runoff. The newer building incorporates four 36-mgd pumps for diverting excess runoff and four smaller sewage lift pumps which pump only to the sewage treatment plant. Nearby, on the other side of the Grand River, are the two new pumping stations, Garfield Avenue and Front Avenue Pumping Stations, both built in 1955. Both pumping stations have two 28.8-mgd pumps for discharging directly into the Grand River and are operated only when the Market Street Pumping Station cannot handle the excess flow. All three pumping stations are interconnected. In addition, there is an overflow outlet at the foot of First Street, where much of the excess flow from the First Street Drainage District is diverted into the Grand River. The overflow outlet is equipped with control gates, so Grand River flood waters cannot enter the sewers. Also, in the immediate downtown area are small separate storm sewers with outlets through the floodwalls. These outlets are all equipped with flap gates or control gates. The new expressways also have a separate drainage system with outlets in the floodwalls. Since the expressways are elevated, Grand River flood water backup into their drainage outlets and system presents no problems.

(6) The Grand River flows through an area of glacial drift, reaching bedrock in the central portion of the city. The drift was deposited by the alternately advancing and receding lobes of a glacier. The glacial drift is sand, gravel, and clay. The soils in the area are primarily these glacial fill deposits, although there are minor strips of alluvium and organic muck along the stream courses. The upland soils, primarily sandy loams or sand with silt loams, are predominantly porous, loose, and well drained, whereas the soils of the flood plains tend to be less well drained because of the greater proportion of silt and lime in the subsoils.

Within Grand Rapids, the soils on the left bank are mostly impervious. Some infiltration problems could be expected, however, on the lower part of the right bank where Plainfield sand predominates.

(7) Grand Rapids, the second largest city in Michigan, is served by the Pennsylvania, Chesapeake and Ohio, Grand Trunk Western, and New York Central railroads and by many good state, Federal, and Interstate highways. Three railroad bridges and nine highway bridges cross the Grand River at Grand Rapids. The 1960 Census reported the population as 177,313.

(8) Grand Rapids is a manufacturing city, a wholesale trade center, and a regional shopping center serving a large area just outside the reach of Chicago and Detroit. It is nationally famous for furniture manufacture. Although today the furniture industry is much less dominant in the area's economy than it was two decades ago, it still is one of the most important industries. In 1950, about one manufacturing worker in six was employed in a furniture factory. Grand Rapids still is striving to maintain a dominant position in better quality furniture manufacturing. However, the fabrication of automobile bodies and other auto parts now employs about as many persons as the furniture factories. Other factories manufacture refrigerators, plumbing supplies, numerous items of machinery, foundry products, and items fabricated of metal. Although no basic steel is produced here, steel is readily available from nearby sources. Merchants throughout much of the Lower Peninsula depend on Grand Rapids as a wholesale supply depot. Its wholesale grocery business is especially large due in part to the large fruit and vegetable farming enterprises along the Lake Michigan shore.

b. Flood problems. The 1904 maximum flood of record in Grand Rapids has been computed to have an exceedence frequency of 1.7 percent; that is, there is a 1.7 percent chance of such a flood being equalled or exceeded in any given year. After the flood of record in 1904, the city of Grand Rapids built a series of floodwalls and levees, with associated interior drainage works. The floodwalls were built to contain the 1904 profile, with a two-foot allowance for freeboard. However, the 1948 flood, which peaked at 42,200 cfs (22 percent less in discharge than the 1904 estimated 54,000 cfs peak), came within two feet of overtopping the floodwalls. This condition was caused by the constricting effects the walls have produced by eliminating the overbank flow area and also by sedimentation effects. Under existing conditions, the city of Grand Rapids is fairly well protected, except for the southwestern portion of the city, against floods producing flows of about the magnitude of the 1948 flood. If the floodwalls were to fail or be overtopped, the damages would be extensive. Based on 1960 price levels and existing physical conditions, average annual damages at Grand Rapids are estimated to be $390,000. The Grand River reaches flood stage at elevation 603.7 feet on the USGS gage, located 500 feet upstream from the Fulton Street bridge. This stage corresponds to a discharge of 28,000 cfs. At elevations just above flood stage, 603.7 feet, widespread flooding occurs in the North Park and

Comstock Park areas north of the City, and leakage at floodwalls begins in several locations downtown, initiating pumping operations. At a stage of 608.3 feet, complete protection is obtained by sandbagging in the vicinity of the Ann Street bridge. At elevation 608.5 feet, overflows begin on the west bank at Pearl Street. By comparison, the stage of the 100-year flood of 61,000 cfs is approximately 611.4 feet. In these studies, Plaster Creek and Indian Mill Creek were investigated to determine whether flooding was primarily due to backwater from the Grand River or the headwaters of the creeks. Using the March 1948 conditions, the peak discharge was calculated for each creek, and stage-discharge relationship was established at a bridge on each creek located within the known flooded areas. The maximum stage heights calculated were found to be well below the recorded highwater marks. This, plus the fact that peak discharges for Plaster Creek and Indian Mill Creek occur three days before the Grand River peak, indicate that flooding adjacent to the creeks is almost entirely due to backwater effects from the Grand River.

c. Average annual damage computations

(1) Flood profiles were developed from known flood elevations and stage-discharge curves computed therefrom by the slope-area method. Using these profiles, flood outlines were drawn on aerial mosaics for flows of 42,000, 54,000, and 70,000 cfs. The flood outlines showed areas of basement flooding, flooding less than two feet of depth, and flooding greater than two feet of depth. Flood outlines for the 42,000 cfs flood were not used, but actual damages reported in the Grand Rapids hearings were used. Also, since it was assumed that a flood of 54,000 cfs might overtop the floodwalls or levees, damages were computed for this flow for both overtopping and non-overtopping of the floodwalls or levees, as shown in Table H-9. The 1962 Grand River Regional Flood Frequency Study was used to determine the frequencies.

(2) The 1960 census data, the aerial photos, and the St. Paul curves were used to estimate residential damages. Figure H-2 shows relationships among flood stage, discharge, and damage. Basement damage was assumed to occur until the greater than two-foot depth was reached, since most of the houses in the area subject to overland flooding have their first floor approximately three feet above the existing grade. Average damage figures for the various price ranges of houses were computed for basement, under two-foot depth, and greater than two-foot depth flooding. These figures were then multiplied by the number of houses in each value category, and damages were computed for discharges of 54,000 cfs (with no overtopping of levees), 54,000 cfs (with overtopping of the levees) and 70,000 cfs. The study catalogued the small commercial, small industrial, large commercial, large industrial, and miscellaneous buildings in Grand Rapids. To obtain representative damage figures, plant managers of 21 industrial companies were interviewed. The companies selected were widely dispersed and varied in nature. Furniture manufacturing companies were investigated in more detail than other industries. Damage evaluation included structural damage, electrical and equipment damage, stock and inventory damage, increased cost of operation, cost of flood fighting, and cleanup costs.

Unit damages developed in this study are as follows:

DAMAGES ASSESSED

Type of damage	Small commercial	Large commercial	Small industrial	Large industrial	Miscellaneous
Basement	$1,050	$ 6,000	$ 2,000	Considered Separately	$ 6,000
Less than 2 ft.	4,500	18,000	15,000		18,000
Greater than 2 ft.	7,800	30,000	24,000		30,000

Using the above unit damages, commercial damages were estimated for the same floods. Stage-discharge, discharge-damage, and discharge-frequency curves were drawn for the index point at the USGS gage at Fulton Street. A damage-frequency curve was developed and an average annual damage of $390,000 was computed. Residual damages for the 100-year design flood were determined to be $190,000, leaving $200,000 as benefits.

d. Solutions considered

(1) The flood prevention measures considered for the Grand River at Grand Rapids were impoundment of the flood flows, channel improvement (including deepening of the channel), and construction of levees and floodwalls. Each of these studies is described in the following paragraphs.

(a) A study of reservoir sites in the Grand River basin indicates that there are 24 potential retarding basins. These studies indicate that only seven of these sites require further study. The seven reservoir sites offering protection to Grand Rapids are:

Smithville Reservoir on Grand River
Williamston Reservoir on Red Cedar River
Okemos Reservoir on Red Cedar River
Portland Reservoir on Lookingglass River
Millett Reservoir on Grand River
Muir Reservoir on Maple River
Labarge Reservoir on Thornapple River

These sites were selected by screening potential flood control reservoirs. Flood routing studies, using various combinations of reservoirs, indicate that the peak discharge for the 100-year flood at Grand Rapids could be reduced from 61,000 cfs to as low as 35,000 cfs; however, as single purpose reservoirs they cannot be economically justified.

TABLE H-9

FLOOD DAMAGE SUMMARY - GRAND RAPIDS, MICHIGAN (Entire city)

RIVER: Grand
RIVER MILE: 40.8
INDEX POINT: Fulton Street Bridge

	1948 flood	1904 flood (no overtopping)	1904 flood (overtopping)	Hypothetical flood
1. Flood stage (USGS elev)	607.5	609.9	609.9	612.9
2. Exceedence freq. (percent)	4.9	1.7	1.7	0.5
3. Discharge (CFS)	42,200	54,000	54,000	70,000
4. Computed residential damages				
a. Units	7	367	4,499	7,103
b. Damages	$17,000	$196,240	$3,479,900	$10,964,470
5. Computed business damages				
a. Units	36	179	778	835
b. Damages	$239,865	$1,605,750	$6,113,075	$13,563,110
6. Totals				
a. Units	43	546	5,277	7,938
b. Damages	$256,865	$1,801,990	$9,592,975	$24,527,580
7. Average annual damages (February 1960 price level)			$390,000	

(b) Deepening of the channel was also considered. However, it was felt that the existing floodwalls would be threatened by undermining. Because of the steep river bottom slope, improvement of the channel bottom would also increase stream flow to such high velocities that the bridge foundations might be threatened.

(c) The plan considered the most suitable was the improvement and extension of the existing floodwalls along with bridge modifications. Protection will extend along both banks; along the left bank the upstream limit is Three Mile Road and the downstream limit is the downstream crossing of I-196 near the sewage treatment plant. The line of protection along the right bank extends downstream from a point 2200 feet north of Ann Street to the downstream crossing of I-196. The existing floodwalls and levees would be heightened to provide a three-foot freeboard over the 100-year flood stage. To meet the two-foot minimum bridge clearance requirement, it would be necessary to replace two concrete arch bridges and to raise three other bridges. The plan of improvement also calls for the removal of the old power dam, which now serves as a beautification dam. This removal would reduce the height requirements for the floodwalls and levees upstream of the dam, and the Sixth Street and North Park Bridges would not have to be raised. The only objection to removal of the dam is that its backwaters make up the waterways within Comstock Park, and without the dam the Grand River bottom is mostly dry and unsightly during low flow. The city of Grand Rapids has built four beautification dams, one to three feet high, to eliminate these conditions below the dam. If the eight-foot high power dam were removed, it should be replaced by smaller beautification dams.

(d) Most of the Grand Rapids interior storm drainage area would be affected by the proposed flood walls and levees. Analysis of the existing pump stations and capacities indicates that they are adequate, but improvements would be made to serve two areas not currently contributing flows to them. The area in the northwest section of Grand Rapids next to the Grand River would require interior drainage facilities: specifically, an open ditch interceptor that would parallel the I-196 expressway to a new pump station. The rural and industrial development of this area would permit construction of an open ditch interceptor there. Outlet facilities presently discharging into the Grand River through the expressway would be closed. Topography in this area prevents the use of gravity outlets. The area located on the east side north of Coldbrook Creek adjacent to the Grand River would be improved. The area lying immediately next to the floodwalls is low; the rest of the area rises rapidly in elevation into the headwater areas. These elevations provide sufficient head to permit discharge of runoff by converting the existing outlet sewers to pressure conduits for the final few hundred feet before outfall into the Grand River. The low-lying area behind the floodwall would require a separate drainage system which would connect to a new interceptor and pump station system. Locations of proposed pressure conduits, interceptor drains, interceptor ditch, and pump stations are shown on Plate H-6, Plan of Protection.

e. Economic analysis. The cost summary shown on the next page includes computations for earth work, concrete work, repairs to existing protection system, interior drainage systems, closure structures, removal of the power dam, and associated costs for the plan of protection at Grand Rapids. Residual average annual damages for the protection plan are $190,000, leaving $200,000 as average annual benefits. Total project average annual cost amounts to $420,700. Hence the benefits to cost ratio is 0.48.

f. Summary of investigation. Previous estimates of the flood damages were updated, using the 1962 regional frequency study on the Grand River basin. A detailed analysis was made of residential, commercial, and industrial flood damages, costs of construction, and benefits to be derived from a plan of improvement. A plan of protection was designed to protect residential, commercial, and industrial structures from a flood of 61,000 cfs (a 100-year flood). The proposed protection system, which would raise existing floodwalls and levees to provide three-foot freeboard over the 100-year flood, would cost $7,895,500. Annual cost, based on amortization at 4-5/8 percent interest, is $420,700, including $13,300 in operation and maintenance costs. The ratio of benefits, $200,000, to annual costs of $420,700 is 0.48 to one. However, benefits shown include no estimate of further growth or land enhancement. Currently, the character of the area immediately west of the river has changed from residential to service type businesses after construction of the expressway. Also, it is considered possible to change the location of the levee in the southwestern portion of the city from the railroad tracks to the edge of the Grand River, with an additional increase in construction cost; compensating land enhancement benefits are obtained for an area of approximately 210 acres. Construction of flood prevention works on the Grand River at Grand Rapids is not recommended at this time because of the unfavorable balance between benefits and cost. However, flood control benefits are available for inclusion in a multi-purpose reservoir project. In conclusion, the city of Grand Rapids is fairly well protected from a flood of the 1948 magnitude. However, were the floodwalls or levees to fail or be overtopped, the damage would reach enormous proportions.

GRAND RAPIDS

Summary, Estimate of Cost (100 year design flood)

A. Non-Federal Cost

Item	Contract	Contingencies	E&D	S&A	TOTAL
Lands (ROW)	$ 33,000	$ 8,300	$ -	$ 3,000	$ 44,300
Highway bridges	1,659,000	414,800	207,400	166,500	2,447,700
Subtotals	$1,692,000	$423,000	$207,000	$168,900	$2,491,900

B. Federal Cost

Item	Contract	Contingencies	E&D	S&A	TOTAL
Levees & Flood walls	$1,619,000	$404,800	$202,400	$144,700	$2,370,900
Interior drainage	1,429,000	357,300	178,700	127,700	2,092,600
Closure	110,000	27,500	13,800	9,900	161,100
R.R. bridges	399,000	99,800	49,900	35,700	584,300
Dam removal	133,000	33,300	16,600	11,900	194,800
Subtotal	$3,690,000	$922,500	$461,300	$329,500	$5,403,500
Total First Cost	$5,382,000	$1,345,500	$668,700	$498,700	$7,895,500

ANNUAL COST SUMMARY

Non-Federal	$2,491,900 x .0516 =	$ 128,600
Federal	$5,403,500 x .0516 =	278,800
Operation and maintenance	$ 266,700 x 0.05 =	13,300
Total Average Annual Cost	=	$ 420,700

Comparison of the average annual cost and the average annual benefit reveals a B/C ratio of $\frac{\$200,000}{\$420,700} = .48$

13. PLAINFIELD TOWNSHIP

a. Description of the area

(1) Plainfield Township is located in the west-central portion of Kent County, Michigan immediately to the north of the city of Grand Rapids. The Grand River meanders through the southern half of the township in a near semi-circular fashion, in the general direction of east to west. The Grand River enters Plainfield Township at river mile 53.5 and leaves at river mile 45.5. In this reach of roughly eight river miles, there is only one bridge: U. S. Highway 131 on Plainfield Avenue at river mile 51.3. Most of the homes in Plainfield Township, therefore most of the flood damages, are in the downstream six miles of the eight mile reach. Within this six mile stretch, a large number of the homes are grouped together in an area two miles in length along the river. Most of the low lying houses in this area are wood-frame dwellings built above the surrounding ground on high foundations or on pilings. The remaining upper two miles of the Grand River in Plainfield Township was not considered for protection since the cost of protective works for the few isolated homes would far exceed the benefits to be derived.

(2) The drainage area of the Grand River at the downstream limit in Plainfield Township (river mile 45.5) is 4850 square miles. One major tributary, the Rogue River, joins the Grand River in Plainfield Township at river mile 51. This tributary contributes 260 square miles of drainage area. There are no USGS gaging stations on the Grand River in Plainfield Township, but there is one just downstream at Grand Rapids at which point the drainage area is 4900 square miles. This gage is located in NE ¼, section 25, T7N, R12W, on the right bank 500 feet upstream from the bridge on Fulton Street in downtown Grand Rapids at river mile 41. Continuous records of stream discharges are available for this gage for the period October 1930 to date. A staff gage with flood stages recorded back to 1947 is privately operated by a resident on Abrigador Trail within the study area.

(3) Plainfield Township has shown a large increase in population from 1940 to date. The 1960 census reported the total number of residents in the township as 11,680 persons, a 94 percent increase over the previous decade and a 201 percent increase from the 1940 figure of 3876 persons. The small unincorporated village of Comstock Park, whose 1965 population is reported as 2500 persons, is in the flood damage area. USGS topographic mapping dated 1918 for Plainfield Township is drawn to the scale of one inch per mile with contour intervals of 20 feet.

(4) Soils in the area are primarily glacial till deposits with minor strips of alluvium and organic mucks along stream courses. The upland soils are pervious sandy loams and sands with some silt loams. They are predominantly porous, loose and well drained because of the large portion of silt and lime in the subsoils.

b. Flood problems. The areas vulnerable to flood damages in Plainfield Township are residential with little industrial or business development. Flood damages, which are experienced almost annually, are mostly direct losses to private dwellings both in real and personal property. Flood losses to crops are negligible, since planting and cultivation begins after recession of flood waters and lowering of the ground water table in the early summer. Many of the homes in the flood plain fall into the category of summer cottages, occupied during the summer months over the weekend or for the vacation period. During the 1947 and 1948 floods, most of the homes in this area were surrounded by about five feet of water. Some of the homes are constructed on high posts or piers to protect them from normal high stages; however, in 1947 most of these homes had water over the first floors. Development of the area has been curtailed because of the flood threat. The most heavily damaged area, between river miles 45.5 and 51.5 (US-131 Highway bridge), experiences periodic flooding in spring and early summer about every other year. The construction of a power dam in Grand Rapids has caused a shoaling effect by decreasing the velocity of the stream with resulting sediment deposits. A result of this shoaling is reduced channel capacity, forcing the rising backwaters to enter the small tributary creeks draining the swampy lowland bordering the river channel, inundating the roadways and housing lying between the low bank of the Grand River and the creek marshlands. Ice jams during the spring breakup, caused by piling and bridge piers, also contribute to flooding conditions. Based on the statements of long-term residents in Comstock Park and vicinity, it appears that bottom elevations of the stream have risen considerably because the normal flow of the Grand River has been impeded downstream by structures. It is reported that at low stages it is possible to wade across the river merely by avoiding the holes, which are to be found at the outer edges of bends or near jutting obstructions at the stream bank. Although loss of life has not been recorded from floods in Plainfield Township, disaster services of County and State organizations and of the local Red Cross units have been called upon frequently to assist in evacuating homeowners and to perform miscellaneous services such as feeding, clothing, and providing temporary shelter.

c. Average annual damage computations. Flood damages were determined for three variable flood stages, namely, the 1904 flood stage, (see Plate H-7) the 1948 flood stage and a hypothetical flood stage. The 1962 Grand River Regional Flood Frequency Study was used to determine the frequencies of these floods. A summary of damages occuring from these flood stages is present in Table H-10. Stage-discharge, damage and discharge frequency, and stage-damage curves for Plainfield Township are shown in Figure H-3.

TABLE H-10

FLOOD DAMAGE SUMMARY - PLAINFIELD TOWNSHIP, MICHIGAN

RIVER: Grand
RIVER MILE: 45.1
INDEX POINT: North Park Bridge - Grand River

	Hypothetical flood	1904 flood	1948 flood
1. Flood stage (USGS elev)	617.8	617.1	615.8
2. Exceedence frequency (percent)	1.0	1.8	5.2
3. Discharge (cfs)	61,000	54,000	42,200
4. Totals			
a. Units	206	202	191
b. Damages	$332,000	$276,100	$190,700
5. Average annual damages (February 1960 price level)		$48,500	

d. Solutions considered

(1) Two solutions were considered for the flooding problem along the Grand River in Plainfield Township. The first plan was for construction of intermittent levees and flood walls at the populated regions; the second plan was for flood plain evacuation.

(a) Levee and floodwall computations (Plan 1). The protection line was designed to be intermittent levees and flood walls. The flood walls would be used only in front of the residences where the right-of-way is limited. The right bank protection line would start 4,000 feet south of the point where the left bank protection line would begin. Both downstream levee limits were just south of the Plainfield Township-Grand Rapids line. No protection was considered necessary on the right bank upstream of the Rogue River confluence. The various right and left bank levee and floodwall lines are shown on Plate H-8 and are described as follows:

1. Left bank protection line. This bank will be protected by 7450 linear feet of levee and 7900 linear feet of floodwall. Heights of this protection line vary from 5.0 feet to 14.0 feet, with the average height being approximately 13 feet. Top elevations vary from 621.5 feet at the downstream limit to 624.5 feet at the upstream limit. Ground elevations at the protection line vary from 608 to 620 feet. The left bank will be protected by levee systems around three separate areas. For the furthest downstream segment, however, it would be less expensive to run the levee up both banks of two small creeks tributary to the Grand River as opposed to providing additional interior drainage pumping. The furthest area upstream on the left bank is small and only protects several isolated dwellings. No closure structures are required on this side of the river.

2. Right bank protection line. This bank would be protected by 14,920 linear feet of levee and 6950 linear feet of floodwall. Heights of the protection line vary from 5.0 feet to 15.0 feet; average height is 11 feet. Top elevations of the left and right bank protection lines would be similar. Ground elevations at the protection line vary from 610 to 618 feet. The right bank would be protected by levee systems around three separate areas. However, at the protection line for Abrigador Trail and Comstock Park, it would be less expensive to run the levee up both banks of the two tributary creeks of the Grand River, as opposed to providing additional interior drainage and pumping. One closure structure is required on this side of the river at North Park Street.

3. For this intermittent system of levees and floodwalls on both banks of the Grand River it was considered necessary to include costs for 10 separate pumping stations, with pumping capacities ranging from 30 cfs to 215 cfs.

(b) Flood plain evacuation (Plan 2). This plan considers the purchase of all damage-prone property and dwellings in the Grand River flood plain from Plainfield Road (US-131) to river mile 45.5. It was found that this plan would be the cheapest method of eliminating the flood hazard. There are 220 residential dwellings totaling $997,000 in value which would have to be bought along both banks. The following tabulation indicates the relatively low values of the houses.

Right Bank			Left Bank		
Dwelling unit cost	No. of dwellings	Cost	Dwelling unit cost	No. of dwellings	Cost
$ 7,000	2	$ 14,000	$ 7,000	7	$ 49,000
6,000	8	48,000	5,000	6	30,000
5,000	61	305,000	4,500	83	373,500
4,000	23	92,000	4,000	9	36,000
3,000	6	18,000			
2,500	6	15,000			
2,000	6	12,000			
1,500	3	44,500			
TOTALS	115	$508,500		105	$488,500

In addition to the 220 dwellings, a total land purchase of 1663 acres would be required, 925 acres on the right bank and 738 acres on the left bank.

e. Economic analysis. The average annual damages along the Grand River from Comstock Park upstream to the US-131 highway bridge are estimated to be $48,500. The following is a tabulation of the data from the four basic curves (stage-discharge, discharge-frequency, stage-damage, and damage-frequency) for Plainfield Township.

	Stage (ft)	Discharge (cfs)	Damage ($)	Freq. (%)
	612.0	16,000	0	57.0
	613.0	21,000	47,000	35.0
	614.0	28,000	96,000	19.0
	615.0	35,800	146,000	9.3
1948 flood -	615.8	42,200	190,700	5.2
	616.0	43,800	202,000	4.5
	617.0	53,400	266,000	1.9
1904 flood -	617.1	54,000	276,100	1.8
100 yr. flood-	617.75	61,000	332,000	1.0
	618.0	63,800	362,000	0.85
	618.55	70,000	440,000	0.50
	619.0	75,800	520,000	0.34
	619.3	78,800	600,000	0.27

The index point was chosen to be the North Park Bridge, at river mile 45.1.

SUMMARY, ESTIMATE OF COST (Plan 1)

A. Non-Federal Cost

Item	Contract	Contingencies	E&D	S&A	Total
Lands	$ 63,000	$ 15,750			$ 94,500
Subtotal	$ 63,000	$ 15,750			$ 94,500

B. Federal Cost

Item	Contract	Contingencies	E&D	S&A	Total
Levees	$ 629,700	$ 157,400	$ 78,700	$ 56,300	$ 922,100
Flood walls	2,985,360	746,300	373,200	266,800	4,371,700
Pump sts's	257,900	64,500	32,200	23,000	377,600
Subtotal Fed.	$ 3,872,960	968,200	484,100	346,100	5,671,400
Total First Cost	$ 3,935,960	$ 984,000	$484,100	$346,100	$ 5,750,200

Annual Cost Summary

Non-Federal	$ 94,500	(.0516)	$ 4,900
Federal	$5,671,400	(.0516)	292,600
	Subtotal		$297,500
Operation and maintenance			10,700
Total average actual cost			$308,200

The total first cost of an intermittent levee and floodwall scheme along both banks is estimated to cost $5,750,200. The total average annual cost at 4-5/8 percent interest over the 50 year life of the project, including $10,700 for operation and maintenance, is estimated to be $198,000. The resulting B/C ratio is $\frac{\$48,500}{\$308,200} = .1573$

SUMMARY, ESTIMATE OF COST (Plan 2)

Federal Cost

Item	Quantity	Unit cost	Contract cost	Contingencies	E&D	S&A	Totals
Lands	1663 acres	$500/acre	$831,500	$208,000	$103,950	$135,135	$1,278,600
Dwellings	220 units	L.S.	997,000	249,000	124,600	89,100	1,459,700
Total Cost			$1,828,500	$457,000	$228,600	$224,235	$2,738,300

@ 100 years and 4-5/8% interest, factor = .0516

Total average annual cost = 0.0516 ($2,738,300) = $141,300

Average annual benefits = $48,500

Average annual cost = $141,300

B/C Ratio = $\frac{\$48,500}{\$141,300}$ = .343

f. Summary of investigation. Neither of the two most suitable schemes for Plainfield Township flood control show indications of preliminary feasibility. If this area were protected with the most suitable protection scheme--levees and floodwalls--the costs to be incurred would far exceed the benefits to be derived; the benefit-cost ratio is .157. It would be more feasible to evacuate the flood plain (benefit-cost ratio .343). Since the two alternative plans investigated are both unfeasible, no further study was attempted at this time. The study reveals a serious flood damage problem on the Grand River just immediately upstream of Grand Rapids in Plainfield Township of Kent County, but a feasible solution to the problem cannot be formulated. It is concluded that no further study of a local protection project at Plainfield Township be made at this time.

14. ADA

a. Description of the area

(1) Ada is located in the central portion of Kent County approximately 10 miles due east of Grand Rapids. The community lies primarily on the left bank of the Grand River, at river mile 62, with the majority of the commercial and residential establishments centered along the Thornapple River, approximately one-half mile upstream from its confluence with the Grand River.

(2) A plant and distribution center has been constructed on the north side of State Highway M-21 by Amway Corporation. The plant was designed for protection from 1904 flood elevations. A shopping center is proposed for the south side of M-21 highway.

(3) The Grand River at Ada drains 4,000 square miles. The Thornapple River, the second largest tributary of the Grand River, drains 849 square miles. The surrounding countryside, beyond the broad flat flood plain at the confluence of the Grand and Thornapple Rivers, is hilly and scenic. Elevations range from 620 feet at the confluence of the rivers to 800 feet on some of the hills immediately south of the city.

(4) Ada Township has shown a large increase in population from 1940 to date. In 1960 there were 2887 residents, a 46.8 percent increase over 1950, and 93.6 percent increase over 1940. The 1965 population of the town of Ada, located within Ada Township, is estimated at 400 persons.

(5) The USGS gaging station nearest to Ada is on the Thornapple River in NW¼, sec. 22, T5N, R10W, on the right bank 200 feet downstream from the Labarge powerplant, 2.3 miles northeast of Caledonia, and 3.3 miles downstream from the Coldwater River confluence. The drainage area of the Thornapple River at the gage is 773 square miles. Continuous records are available for the periods October 1930 to September 1938 and from October 1951 to date. The USGS gaging station nearest to Ada on the Grand River is located at Grand Rapids. The nearest Weather Bureau gaging station on the Grand River is located at Lowell. State highway M-21 crosses the Grand River near Ada, and three bridges cross the Thornapple River at Ada: the Thornapple River Road bridge, a covered pedestrian bridge, and the Grand Trunk Western Railroad bridge.

b. Flood problems. Flood damages in the town of Ada are experienced periodically, but are small due to the small size of the community and the sparse flood plain development (see Figure H-4). In the 1950 flood, the most recent for which damages were estimated, the total damage at Ada is estimated at $4,400 (1960 price level). All of the damages were basement damages to residential units and commercial establishments. The 1904 flood outline is shown on Plate H-9.

c. Average annual damage computations. Flood damages were determined for the 1904, 1948, and 1950 flood stages. The 1962 Grand River Regional Flood Frequency Study was used to determine the frequencies of these floods. Damages incurred for these floods are summarized in Table H-11.

d. Solutions considered. The only effective method of controlling the flooding at Ada is a levee system. Other methods of flood control would be too costly. (See Plate H-10)

e. Economic analysis. Two separate levee lines are necessary to control the flooding at Ada. The alignment of the levees is shown on Plate H-10, Plan of Protection. Levee 1, which is 1500 feet long and 2.2 to 7.2 feet high, requires 7600 cubic yards of fill material. Levee 2, which is 4200 feet long and 2.2 to 7.2 feet high, requires 104,300 cubic yards of fill material. Levee 1 requires 1.3 acres of right-of-way; levee 2 requires 2.7 acres. A pump station to handle interior drainage of 33 cfs capacity would have to be provided. No closure structures are necessary for the streets, since sandbagging would be adequate.

SUMMARY ESTIMATE OF COST

A. Non-Federal Cost

Item	Contract	Contingencies	E&D	S&A	Totals
Lands (ROW)	$ 1,000	$ 250	$ 125	$ 100	$ 1,475
Subtotals Non-Federal	$ 1,000	$ 250	$ 125	$ 100	$ 1,475

B. Federal Cost

Item	Contract	Contingencies	E&D	S&A	Totals
Fill material	$280,000	$ 70,000	$ 35,000	$25,000	$410,000
Pump station	39,600	9,200	4,900	3,500	57,200
Subtotals Federal	$319,600	$ 79,200	$ 39,900	$28,500	$467,200
Total First Cost	$320,600	$ 79,450	$ 40,075	$28,600	$468,700
				SAY	$468,700

ANNUAL COST SUMMARY

Non-Federal	$ 1,475 (0.0516) =	$ 80
Federal	467,200 (0.0516) =	24,100
Subtotal		$24,180
Operation and maintenance		600
Total average actual cost		$24,780

TABLE H-11

FLOOD DAMAGE SUMMARY - ADA, MICHIGAN

RIVER: Grand
RIVER MILE: 61.9
INDEX POINT: M-21 Highway Bridge-Grand River

	1904 Flood	1948 Flood	1950 Flood
1. Flood State (USGS evel.)	628.2	626.4	623.2
2. Exceedence freq. (percent)	1.5	4.5	20
3. Discharge (CFS)	52,500	41,000	26,000
4. Computed residential			
a. Units	15	13	5
b. Damages	$12,730	$ 7,200	$ 2,700
5. Computed business damages			
a. Units	3	3	1
b. Damages	$13,360	$7,840	$ 1,200
6. Miscellaneous damages			
a. Consumers power plant damages	$ 5,000	$ 3,000	0
b. Roads damages	$ 3,000	$ 1,000	$ 500
7. Totals			
a. Units	18	16	6
b. Damages	$34,090	$19,040	$ 4,400
8. Average annual damages (February 1960 price level)		$ 3,480	

The costs included in the levee design are earthwork, pumping station, right-of-way, and other associated costs. The total first cost of the protection scheme is estimated to be $468,700, which, amortized over a 50 year period at 4-5/8 percent interest, gives an average annual cost of $24,180. Operation and maintenance is estimated at $600, bringing the total annual cost to $24,780. The average annual damages after construction (residual damages) would be $240. Subtracting the residual damages from the total average annual damages of $3480 gives average annual benefits ($3240). Comparison of the average annual benefits and costs gives a benefit-cost ratio 0.13.

f. Summary of investigation. The results of the preliminary studies indicated that levees were the only acceptable solution to the Ada flood problem. However, the benefit-cost ratio of 0.13 indicates an unfeasible solution and no further study of a flood control project at Ada will be made at this time.

15. LOWELL

a. Description of the area

(1) The city of Lowell is located in the northeast portion of Lowell Township in eastern Kent County. This community lies about 17 miles east of Grand Rapids, the largest city of western Michigan. The 1960 population of Lowell was 2545 persons, a 16 percent increase in population over the preceding decade. Lowell is located on the right (north) bank of the Grand River at the confluence with the Flat River which enters from the north. At this point, the Grand River drains an area of 3640 square miles of which 556 square miles are drained by the Flat River. The nearest USGS gaging station on the Flat River is at Smyrna. The drainage area of the Flat River at this gage is 528 square miles; records are available from October 1950 to date. The USGS gaging station nearest to Lowell on the Grand River is located 17 river miles upstream. The drainage area at this gage is 2840 square miles; continuous records are available from July 1951 to date. The nearest gaging station on the Grand River downstream from Lowell is 29 river miles away at Grand Rapids. The drainage area at this gage is 4900 square miles. The U. S. Weather Bureau operates and maintains a wire weight recording gage on the Grand River at Lowell. This gage has been used as the index point for the damage studies.

(2) The Flat River bisects the community of Lowell into two nearly equal parts. A dam with an overflow spillway intercepts the Flat River at Main Street about 0.6 miles upstream from the mouth, and a wooden trestle carries the Chesapeake and Ohio Railway across the river 0.1 mile downstream of the dam. Lee Creek, a minor tributary to the west of the Flat River, flows through the southwestern portion of the town and empties into the Grand River one mile downstream from the mouth of the Flat River. Lowell is located on the slope of a typical glacial moraine common to central Michigan and the Grand River basin. Elevations range

within the city limits from 720 feet near the northwestern outskirts to 620 feet along the banks of the Grand River. Glacial drift covering bedrock in the area to a depth of about 70 feet at the river to 220 feet at the higher ground surface elevation is composed of a mixture of clay, sand, and gravel. The underlying bedrock is composed of the Saginaw sandstones and shales, the Bayport limestones and sandstones, and shales of the Michigan formation, all of the carboniferous age. Soils in the area consist mainly of sandy loams with patches of loams and clay loams locally.

(3) Average stream slopes in the vicinity range from two feet per mile in the Grand River to five feet per mile in the Flat River. Downstream from Lowell the slope of the Grand River decreases as it approaches Lake Michigan.

(4) Five bridges cross the Grand River and Flat River in Lowell. The Chesapeake & Ohio Railway maintains a steel through truss bridge over the Grand River and also a timber trestle over the Flat River. A county highway bridge and a state highway bridge, both steel through truss structures, cross the Grand, and a three-section concrete slab bridge carries state highway M-21 over the Flat River.

(5) Lowell and vicinity, depending on agriculture as the principal source of revenue, has experienced a slow rate of economic growth. Despite this fact, the city has increased its rate of population growth over that of nearby small towns. Industrialization has not been significant in Lowell, as most of the labor force is engaged in commercial retail sales, personal services and farm labor. The most important processing plant is a grain-mill which derives its power from hydro-energy on the Flat River. The city is well served by bus and railway facilities. State highways M-21 and M-91 carry traffic eastward and westward across the state, and southward to the interstate highway system. The area is also served by the main line of the Chesapeake & Ohio Railway connecting Muskegon and Grand Rapids with Detroit and points south.

b. Flood problems. The severest flood of record at Lowell occurred in 1904 when floodwaters were reported to have reached an elevation of approximately 633.7 feet above mean sea level datum. The discharge at this stage is estimated to be 44,000 cfs. Damages at Lowell for a recurrence of this flood are estimated to be $478,000 (1960 price level). In such a flood, 243 residential and 41 business units would be damaged.

c. Average annual damage computations. Various newspaper articles noted the flow of Flat River floodwaters overland across Monroe Street toward the Grand River. It was realized that complex physical and coincidental frequency relationships exist in Lowell. Before a damage frequency relationship compatible with relationships used in the remainder of the Basin can be developed for Lowell, a method to deal with Lowell's conincidental flood problem must be developed. The method adopted followed these steps: The observed 1948 flood data was used to establish the characteristic

hydrograph for the Grand River and the Flat River. Time-discharge interrelationships between these two rivers can be depicted from this data. A full range of flow data was insured by developing hydrographs for both rivers for flows equivalent to floods of 50, 20, 10 and 5 year frequency interval. Next, a family of rating curves on the Flat River, upstream of the Kings Mill Dam, were developed corresponding to various stages and discharges of the Grand River. Again the 50, 20, 10, and 5 year flood frequency disharges were used. Using the above relationships it is possible to take a specific frequency flow on the Grand River, and, using the hydrograph relationship to the Flat River, establish the flow and then the stage of Flat River. Thus the flooding related to the Grand River and its flood frequency may be established and analyzed. In like manner, the flooding related to the Flat River and its flood frequency may be analyzed. Then, by checking the effect of both rivers, the damage may be assigned to the appropriate river, or, if desired, separated for independent study. Damages at Lowell were computed using the Grand River as the major flood contributor. Using the method described above, the following relationships between the Grand and Flat Rivers were obtained:

Year of flood	Grand River Flow (cfs)	Grand River Elev. - USGS	Flat River Elev. - USGS
1904	44,000	633.7	635.8
1948	32,000	630.6	632.8
1950	21,250	628.0	629.8

These developed stages generally agreed with photographs taken of the flooding at Lowell. Since the depth of overland flow was not known, it was decided to use the Flat River elevations for areas north of Main Street and the Grand River for elevations south of Main Street. The extent of inundation of the 1904 flood at Lowell is shown on Plate H-11. Damages were computed for the 1904, 1948, and 1950 floods. This data in turn, was used to develop average annual damages which are summarized in Table H-12. Flood stage, discharge, and damage relationships are shown in Figure H-5.

d. Solutions considered. Flood control reservoirs were considered as a solution to Lowell's flood problem. The details are discussed in the Flood Control Reservoir Studies (Section IV) under "Reservoirs Downstream of Lansing". Consideration was also given to channel improvement by straightenings, widening and deepening. The extensive nature of this undertaking, the cost of acquiring land for cutoffs and rights-of-way for clean-out and widening, and the lack of sufficient fall of the land surface downstream from Lowell toward the mouth of the Grand River indicate an unfavorable balance of benefits to costs. Consideration was finally given to a strictly localized flood prevention measure, that of protection by a levee system augmented by a pumping station to discharge interior drainage accumulating on the landward side of the levee. This plan seemed to have the best chance of showing a favorable benefit-cost ratio.

TABLE H-12

FLOOD DAMAGE SUMMARY - LOWELL, MICHIGAN

RIVER: Grand
RIVER MILE: 70.0
INDEX POINT: USWB Gage
(On M-91 Highway Bridge 1/4 mile d/s from Flat River confluence)

	1904 Flood	1948 Flood	1950 Flood
1. Flood Stage (USGS elev.)			
Grand River	633.7	630.6	628.0
Flat River	635.8	632.8	629.8
2. Exceedence freq. (percent)	2.3	7.5	23.0
3. Discharge (cfs - Grand)	44,000	32,000	21,250
4. Computed Residential Damages			
a. Units	243	186	105
b. Damages	$383,036	$112,935	$48,586
5. Computed Business Damages			
a. Units	41	18	10
b. Damages	$ 84,100	$ 22,220	$ 8,700
6. Miscellaneous Damages			
Roads	$ 11,000	$ 6,000	$ 1,000
7. Totals			
a. Units	284	204	115
b. Damages	$478,136	$141,155	$58,286
8. Average annual damages (February 1960 price level)		$54,200	

c. Economic analysis. A detailed analysis was made of the flood damages, costs of construction, and benefits to be derived from a plan of improvement. Plate H-12 illustrates the proposed plan of protection.

a. The design considerations are summarized below:

Protection designed for 100 year occurrences with three-foot freeboard:

Design flood (cfs)	Design freq. (%)	USGS Grand elev. flood	USGS Grand elev. design	USGS Flat elev. flood	USGS Flat elev. design
54,000	1	636.8'	639.8'	637.6'	640.6'

Design Computations

	Levee No. 1 (west)	Levee No. 2 (east)
Ave. ground (Grand)	629' ±	625' ±
Ave. Ground (Flat)	-	637' ±
Ave. Height (Grand)	11' ±	15' ±
Ave. Height (Flat)	-	3' ±
Total levee length	7,700'	6,800'
Quantity (cu. yds.)	117,400	145,000
	Floodwall #1 (west)	**Floodwall #2 (east)**
Ave. Stream Bt. (Grand)	617' ±	615' ±
Ave. Stream Bt. (Flat)	622' ±	621' ±
Ave. ht. (Grand)	24' ±	24' ±
Ave. ht. (Flat)	19' ±	20' ±
Total floodwall length	1,700'	3,500'

The average annual residual damages remaining after construction of the proposed project would be $5,500 resulting in average annual benefits of $48,700.

b. Cost for the proposed plan of protection is estimated and summarized as follows:

(1) Non-federal cost

Item	Contract	25% Contingencies	E&D	S&A	Totals
Lands	$ 10,000	$ 2,500	$ 1,300	$ 1,000	$ 14,800
Buildings	80,000	20,000	25,000	9,100	134,100
Subtotals	$ 90,000	$ 22,500	$26,300	$10,100	$148,900

(2) Federal cost

Item	Contract	25% Contingencies	E&D	S&A	Totals
Levees & Floodwalls	$1,614,000	$403,000	$202,000	$144,200	$2,363,200
Pump Sta.	1,496,000	374,000	187,000	133,705	2,190,700
Closures	55,000	14,000	6,900	4,900	80,800
Subtotals	$3,165,000	$791,000	$412,900	$282,805	$4,634,700
Total	$3,255,000	$813,500	$437,200	$292,905	$4,783,600

(3) Annual Cost Summary

Based on 100 years

Non-Federal	$148,900 x .0516 =	$ 7,700
Federal	$4,783,600 x .0516 =	246,800
		$254,500
O&M 5%		8,100
Total		$262,600

B/C Ratio $\frac{48,700}{262,600} = 0.185$

The levee and floodwall system was determined to be economically non-feasible, the benefit-cost ratio being .185 to one.

f. Summary of investigation. The community of Lowell experiences floods as often as once in three years. Most damage is confined to basements in those dwellings bordering the flood plain of the Grand River. The exceptional floods of 1904, 1948, and 1950, when losses reached totals of $478,136, $141,155, and $58,286 respectively, occur with frequencies ranging from once every 44 years to once every four years respectively. Hence, the benefits to be derived in the Lowell area by conventional means of flood protection are high: the average annual benefit for protection against 100-year floods is $48,700. However, the cost amounts to $262,600 on an average annual basis. The resulting benefit-cost ratio of 0.185 indicates that this is not an economical solution.

16. SARANAC. Analysis of all available data on the flood problem at Saranac indicates that it would take a flood of the 1904 magnitude to cause any damage at Saranac. Damages caused by even a flood of this magnitude would be minimal. Consequently, no flood protection schemes were considered for the village of Saranac. The majority of the residences and commercial establishments are located on high ground and field reconnaissance reveals that new homes in Saranac are also being constructed on high ground.

17. IONIA

a. Description of the area

(1) The Grand River flows past the community of Ionia in a southwesterly direction. The Grand River at Ionia has a drainage area of 2840 square miles, 51 percent of the basin. The stream at this point ranges from 100 feet to 300 feet in width between primary banks, which rise 6 to 18 feet above the bed of the river. The flood plain at Ionia, through which the river flows in a series of smooth wide bends, is from 2100 feet to 4200 feet broad. Stream-bank elevations rise from a minimum of 625 feet. Flood height of the 1904 flood reached an elevation of 643.5 feet. The terrain immediately beyond the flood plain limit rises abruptly to 760 feet within the city limits of Ionia, less than 3000 feet from the thread of the river. The countryside along the Grand River near Ionia is representative of the morainal land surface formed by the advance and retreat of the Saginaw ice lobe during the Pleistocene glacial epoch. The course of the Grand River at Ionia follows the border of the glacial lake formed by melting ice of the Saginaw lobe. Exposures of bedrock of Pennsylvanian age appear near the city of Ionia. Soils of the upland moraines consist primarily of sands, gravels, clays, and silts deposited by glacial action. The surface of the flood plain is covered by glacial lakebed sands, silts and clays, whereas the streambed material is recent alluvium. The stream slope in the vicinity of Ionia is 1.2 feet per mile in the 18-mile stretch between Lyons at river mile 96 and Saranac at river mile 78. Downstream from Ionia, the river averages a drop of only one-half foot per mile in completing its run to Lake Michigan.

(2) The population of the city of Ionia has increased a nominal 5.3 percent in the 1950-1960 decade. The 1960 population was 6754 persons. The USGS gaging station at Ionia is in NW¼, Sec. 30, T7N, R6W on the left bank of the river 15 feet downstream from the bridge on State Highway M-66. This puts it at river mile 87.5 and about 2.7 miles downstream from the Prairie Creek confluence at the eastern edge of the city. The drainage area of Prairie Creek at its mouth is 103 square miles and drains the lands immediately north of Ionia. At this USGS gage, the drainage area upstream is 2840 square miles. Complete records of stream discharges are available for the period July 1951 to September 1964.

(3) Two highway bridges cross the Grand River at Ionia. In addition, a highway bridge and railroad bridge pass over Prairie Creek at the eastern city limits of Ionia. Two railroad bridges cross the Grand River on either side of the town beyond the city limits.

(4) Ionia, the seat of Ionia County, contained 16 percent of the county population in 1960. A few small industries are located in the city. A large source of revenue in the form of wages and sale of supplies is derived from two state institutions: the Michigan Reformatory and the Ionia State Hospital. Farming provides the greatest source of livelihood to the area. Small grains, wheat, oats, and field corn lead in crop production; the county ranks fifth in State production of cattle and sheep. Ionia County has limited mineral resources--sand and gravel for road construction and concrete aggregate. There are two major railroad connections: the Chesapeake and Ohio Railway and the Grand Trunk Western Railroad. Two state highways, M-21 running east-west and M-66 running north-south, pass through the city. The latter highway connects Ionia with Interstate Highway I-96, seven miles to the south. Commercial navigation plays no part in the economy of Ionia. The nearest hydroelectric power dams, all on the Grand River, are the Webber dam upstream from Ionia at river mile 102.2, the Portland dam at river mile 109.3, and two dams in Lansing at river miles 152.9 and 155.5. The first is privately owned; the latter three are municipally owned and operated.

b. Flood problems. The maximum flood of record at Ionia, the flood of 1904, is computed to have an exceedence frequency of one percent. That is, there is a one percent chance of such a flood being equalled or exceeded in any given year. When the waters of the Grand River reach the elevation 630 feet, they begin to overflow into the broad flood plain at Ionia. Damages are widespread, but minor in nature, being confined to agricultural losses on surrounding small farms and at the County Fair Grounds for the first one to two feet of inundation. However, urban damages are experienced as the waters rise above elevation 635 feet. Damages from a recurrence of the 1904 flood would occur to 350 residential and business units within Ionia (See Plate H-13). Stage-discharge, discharge frequency, stage-damage, and damage-frequency curves are shown in Figure H-6.

c. Average annual damage computations. Damage estimates were made for flood stages recorded for the 1904, 1948, and 1950 floods. Frequencies of these floods were determined from the 1962 Grand River Regional Flood Frequency Study. A summary of damages associated with these floods are presented in Table H-13.

d. Solutions considered

(1) Reservoir channel improvement and levee construction were considered as possible measures of flood control.

(2) Reservoir sites were proposed upstream of Ionia, but it was apparent that the single-purpose reservoir construction costs could not be justified when compared to the benefits found in Ionia.

(3) Straightening the meanders of the river at Ionia also was unfeasible for both physical and economic reasons. Deepening to improve the gradient as a means of increasing stream flow capacity is limited by the flat slope of the stream bed. Any modification of the stream profile below Ionia would require an extensive change in the existing regimen of the stream to the possible detriment of downstream areas. The channel improvement considered for the plan of protection begins at the Cleveland Street bridge and proceeds in a straight line in a direction slightly to the south of west and ties back into the existing Grand River channel approximately one-half mile downstream of the Fairgrounds. Levees were included on both sides of the river to contain the profile for the 1904 design flood. The length of the diversion channel is 9500 feet and the direction chosen from the Cleveland Street bridge would send it through the M-66 bridge opening. Construction of a levee system would be an effective means of reducing flood hazards and flood losses at Ionia. A relatively small acreage of the least valuable land along the riverbank would be removed from higher use, and the comparative costs of construction are less than those fo. competing methods of protection. Moreover, containment of floodwaters within the stream channel will not disrupt the present downstream regimen, if at all, to the degree to be expected by channel rectification.

e. Economic analysis

(1) The average annual cost of channel improvements, including excavation, lands, interior drainage facilities, and raising of both Cleveland Street and M-66 bridges, amortized over 50 years at 4-5/8 percent interest, is estimated to be \$384,300. Comparing this cost to the average annual damages gives a benefit-cost ratio equal to $\frac{\$50,000}{\$384,300}$ or 0.13.

(2) The levee alignment is shown on Plate H-14, Plan of Protection. The design flood used for this levee design was the 1904 flood. From the USGS data sheets it was noted that the stage of this flood at the gage was 27.60 feet. Adding this to the datum of the gage, 615.38, gave

TABLE H-13

FLOOD DAMAGE SUMMARY - IONIA, MICHIGAN

RIVER: Grand
RIVER MILE: 87.5
INDEX POINT: USGS Gage (D/S from State Highway M-66)

	1904 Flood	1948 Flood	1950 Flood
1. Flood Stage (USGS elev.)	643.5	639.7	637.2
2. Exceedence freq. (percent)	0.9	5.0	16.0
3. Discharge (cfs)	45,000	30,000	20,800
4. Computed residential damages			
a. Units	291	135	82
b. Damages	$268,200	$ 45,790	$22,430
5. Computed business damages			
a. Units	59	36	26
b. Damages	$206,300	$ 58,100	$39,900
6. Miscellaneous damages			
Roads	9,000	2,000	0
7. Totals			
a. Units	350	171	108
b. Damages	$483,500	$105,890	$62,330

8. Average annual damages (February 1960 price level) $50,000

a design flood elevation of 642.98 which was assumed to be 643.0 feet. Adding a 3.0-foot freeboard to this gave a top of levee elevation of 646.0 feet.

Design flood (cfs)	Design frequency (percent)	Peak elev. of design flood (feet)	Design levee top elevation (feet)
45,000	0.9	643.0	646.0

The total length of protection required on the right bank is estimated to be 13,600 linear feet, and the amount of levee fill material along this length to the required elevation of 646 feet is estimated to be 212,124 cubic yards. The pumping station to handle the interior drainage problems is estimated to require a 745 cfs capacity unit. Five closure structures are required: two on the Grand trunk railroad bridge, one on the M-66 highway bridge, one on the Cleveland Street bridge, and one on the Chesapeake and Ohio railroad bridge. The total length of protection on the left bank is estimated to be 5000 linear feet and the amount of levee fill material is estimated to be 54,648 cubic yards. The pumping station on this bank to handle interior drainage would require a 168 cfs unit. No closure structures are required.

SUMMARY, ESTIMATE OF COST (1904 Design Flood)

A. Non-Federal Cost

Item	Contract	Contingencies	E&D	S&A	Totals
Lands (ROW)	$ 5,300	$ 1,300		$ 500	$ 7,100
Subtotals Non-Federal	$ 5,300	$ 1,300		$ 500	$ 7,100

B. Federal Cost

Item	Contract	Contingencies	E&D	S&A	Totals
Levees	$ 692,400	$173,100	$ 86,500	$61,900	$1,013,900
Pump Sta.	1,095,000	274,000	137,000	97,900	1,603,900
Closures	29,400	7,350	3,700	2,600	43,100
Subtotals Federal	$1,816,800	$454,450	$227,200	$162,400	$2,660,900
Total First Cost	$1,822,100	$455,800	$227,200	$163,000	$2,668,000

Annual cost summary

Non-Federal	$ 7,100 x .0516 =	$ 370
Federal	2,668,000 x .0516 =	137,700
		$138,000
Operation and maintenance		$ 4,500
Total average annual cost		138,000

The project was amortized over a 50 year period at 4-5/8 percent interest. The average annual damage remaining after construction of the project would be $5000. Subtracting the residual damages from the total average annual damages of $50,000 gives the average annual benefits of $45,000. A comparison of the average annual costs and benefits gives a benefit-cost ratio of .326.

f. Summary of investigation. Flood prevention measures at Ionia are highly desirable, but economic justification of a project is not feasible. The flood problem has resulted primarily from encroachment upon the natural flood plain. A levee system designed to protect residential and business blocks would be the most effective and least costly method of protection. However, since the cost of construction for such a system would exceed the benefits to be derived, it was concluded that no further study of a flood control project at Ionia is justified at this time.

18. LYONS

a. Description of the area

(1) The village of Lyons is located in the east-central portion of Ionia County in Lyons Township. The community of Lyons lies on both banks of the Grand River at river mile 96, immediately south of the confluence of the Grand and Maple Rivers. Muir, a small community adjoining Lyons to the north, lies mainly on the right bank of the Maple River at this confluence; however, since flood damages here are negligible, no estimate has been made of average annual damages or project costs. The Grand and Maple rivers at their confluence drain areas of 1777 and 956 square miles respectively. Elevations in this vicinity range from 640 feet, mean sea level datum, at the river to 760 feet on some of the hills of the surrounding countryside. The Grand River falls approximately 12 feet between river miles 98 and 93, with a slope at Lyons of about 2.4 feet per mile. The population growth rate of these two small neighboring communities is shown in the following table:

TOWN	1940	1950	1960
Muir	447	466	610
Lyons	596	683	687

(2) The nearest USGS stream gaging stations on the Grand River are located downstream at Ionia (2840 square miles of drainage area) and upstream at Portland (1385 square miles of drainage area). The nearest gage on the Maple River is located at the community of Maple Rapids where the drainage area is 434 square miles as compared to the 956 square miles of drainage area at its mouth. The primary transportation routes in and out of the Lyons-Muir area are state highway M-21 and the Grand Trunk Railroad. The only bridge crossing the Grand River at Lyons is located at Bridge Street.

b. Flood problems. Flood damages are experienced periodically at Lyons. The greatest flood of record was caused by ice jams during the 1887 flood. The Lyons Herald Flood Edition, dated 18 February 1887, listed approximately 70 places that received some flood damage. No estimate of a total dollar damage was indicated in the article. The second highest flood of record occurred in 1904 and, according to notes on hand, it was approximately five feet lower than the 1887 flood. Flood waters for the 1904 flood generally covered the business area of Lyons to a depth of one foot and several houses in the south part of the village to a depth of two feet over the first floors. The 1947 flood washed out the dam at Lyons. As a result, no damage was reported at Lyons for the greater 1948 flood, which inundated many other main-stem communities in the Basin. (See Plate H-15)

c. Average annual damage computations. Damage estimates were made from 1904 and 1947 flood stages at Lyons. The 1962 Grand River Regional Flood Frequency Study was used to determine the frequencies of these floods. Damages incurred for these flood stages are summarized in Table H-14. Figure H-7 shows relationships among flood stage, discharge, and damage.

d. Solutions considered. A levee system was the only type of protection which seemed to provide a reasonable degree of feasibility at Lyons. The flood control plan includes an earth-fill levee, a closure structure at Bridge Street, a pumping station, clearing of buildings and land, and acquisition of right-of-way (see Plate H-16). Other methods of flood control would be too costly for the amount of benefits to be derived. No solutions were considered for Muir since the flooding problems appear to be minor.

TABLE H-14

FLOOD DAMAGE SUMMARY - LYONS, MICHIGAN

RIVER: Grand
RIVER MILE: 96.0
INDEX POINT: Lyons Dam

	1904 Flood	1947 Flood
1. Flood Stage (USGS elev.)	653.8	650.0
2. Exceedence freq. (percent)	0.95	12.5
3. Discharge (cfs)	32,600	16,000
4. Computed residential damages		
a. Units	13	3
b. Damages	$26,000	$3,100
5. Computed business damages		
a. Units	12	5
b. Damages	$33,030	$1,450
6. Total damages		
a. Units	25	8
b. Damages	$59,030	$4,550

7. Average annual damages - $2,730
(February 1960 price level)

e. Economic analysis

(1) Only one levee line was considered for protection at Lyons, with a break near the middle at the Bridge Street closure structure. This compacted earth-fill levee would be 3080 feet long and would require 19,650 cubic yards of fill material. The alignment of this levee is shown on Plate H-16, Plan of Protection. Most of this levee would require a nine-foot height. Costs for the one closure structure are assumed on a lump sum basis. The pump station is designed to drain 32.9 acres and 17 cfs of interior drainage. Clearing and grubbing cost includes removal not only of the usual trees and brush but also of houses and one warehouse. Three acres of right-of-way are also required.

SUMMARY ESTIMATE OF COST

A. Non-Federal Cost

Item	Contract	Contingencies (25 percent)	E&D	S&A	Totals
Lands (ROW)	$ 29,000	$ 7,300			$ 36,300
Subtotals Non-Federal	$ 29,000	$ 7,300			$ 36,300

B. Federal Cost

Item	Contract	Contingencies (25 percent)	E&D	S&A	Totals
Fill material	$ 49,125	$12,260	$6,100	$4,400	$ 71,900
Pump station	25,500	6,380	3,190	2,300	37,400
Closure street	1,000	250	130	100	1,500
Clearing	1,500	375	190	140	2,300
Subtotals Federal	$ 77,125	$19,265	$9,600	$6,900	$113,100
Total First Cost	$106,125	$26,600	$9,600	$6,900	$149,400

Annual Cost Summary

Non-Federal	$ 36,300 x .0516 =	$ 1,900
Federal	149,400 x .0516 =	7,700
		$ 9,600
Operation and maintenance	=	577
Total average annual cost	=	$10,177
	SAY	$10,200

(2) The economic study and the protection plan were based on 1931 survey data, 1951 aerial photographs, and a visit to the area. The total first cost of the flood protection scheme was estimated to be \$149,400. This sum, amortized over a 50 year period at 4-5/8 percent interest, gave an average annual cost of \$9,600. Total annual cost of \$10,200 includes \$577 annual costs for operation and maintenance. The average annual flood damage for Lyons was estimated to be \$2729. The annual residual damages would be \$815. By subtracting the residual damages from the average annual damages, the average annual benefits are computed to be \$1914. A comparison of the average annual benefits and costs gives a resulting benefit-cost ratio of $\frac{\$1,914}{\$10,200} = 0.188$.

f. Summary of investigation. The results of the preliminary flood control studies at Lyons indicate that levees are the most physically acceptable solution to the flood problem. However, the relatively small amount of benefits to be derived, when compared to the cost, indicates a non-feasible project. Consequently, no further study of a flood control project at Lyons is justified at this time. Also, it was found that the small nearby community of Muir has negligible flood damages; therefore, it was not considered for a protection scheme.

19. PORTLAND. From previous reports it appears that flood damage at Portland is not caused principally by excessive discharges of the Grand or Lookingglass Rivers, but rather by ice jams. Immediately downstream of the village, the Grand River makes a horseshoe bend and ice jams are formed here and at the various bridges in the village. In the 1904 flood, basements were flooded on the west side of Kent Street, while along River Street first floor flooding was experienced. At the Portland dam, the north abutment and about 20 feet of the dam were washed away, the powerhouse was shut down and the Chesapeake and Ohio Railroad tracks also received some damage. In 1920, this community reported flood damages estimated at \$40,000, but it appears that most of the damage would not have occurred if an ice jam had not formed at the railroad bridge. The 1947 flood, which inundated many urban areas in the Grand River basin, caused very little damage in the village of Portland. Portland's Village President at that time reported \$2,000 total damages and indicated that the damage was low because no ice jam occurred. In 1951, ice jam conditions occurred on the Grand River at Portland and damage was estimated at \$50,000. At this time, the ice blocked all the river channel except a small portion flowing along the right bank. This localized flow undermined the foundations of two buildings adjacent to the bank and caused the rear portions of the buildings to collapse. Further study of a flood control project at Portland is not considered warranted since the problem is one of ice formations rather than excessive river discharges. The community is located on relatively high ground and without the ice jams, the natural and high flows of the Grand and the Lookingglass Rivers do not produce flooding.

20. GRAND LEDGE. Due to the steepness and height of the river banks at Grand Ledge the community seldom suffers flood damages. The only building vulnerable to flooding was a large dance hall on a resort island near the center of the village. This hall was an old structure, in poor condition, which has recently been razed. During the 1948 flood, some sandbagging was necessary around the dam located downstream from the village opposite Fitzgerald Park, another recreation area. It is reported that this dam was built by a resort operator to enable him to run a steamboat from Grand Ledge Island to the downstream park. After the 1947 flood the Mayor of Grand Ledge indicated that there was no damage to any property in the village due to the flood. Water did find its way into a few basements; however, it was indicated this was a storm sewer system problem. The Mayor estimates this damage at $250 and stated that a proper sewer system design would eliminate this basement flooding problem. Upstream of Grand Ledge, the flat river valley, used mainly for farming, was inundated but not seriously damaged in 1947. The Grand Ledge newspaper of April 10, 1947, stated that normally the water level reads at the four-foot mark on the Weather Bureau staff gage, but the high waters caused it to read near the 12-foot mark. Due to the steep, high banks in this community, flooding damages are minor, being limited to basement flooding which the local people feel is a sewer problem. Therefore, no preliminary investigation of a protection scheme was made.

21. LANSING AND VICINITY

a. Description of the area

(1) Based on the "Flood Control Review Report (of Survey Scope), Grand River, Michigan (with particular reference to Lansing, Michigan and vicinity)," dated February 1955, a proposed flood control project (Senate Document No. 132, 84th Congress, 2nd Session, dated 27 June 1956) at Lansing and vicinity was authorized by Congress, (Flood Control Act approved 3 July 1958), but construction funds have yet to be appropriated. This report summarizes the flood problems, recommends a solution, and economic analysis of the project as contained in the Survey Report and as updated based on later data and conditions.

(2) The damage area inundated by the April 1947 flood includes considerable residential, commercial, industrial, and public property, limited farm areas, and appreciable low vacant land immediately adjacent to the rivers. Normally the peak discharge on the Red Cedar River reaches the junction with the Grand River a few hours before the peak discharge of the Grand River arrives. However, because of the relatively broad crest of the flood hydrographs this timing has little effect on the combined peak discharge in the area. The maximum flood of record at Lansing was in March 1904, with floods of lesser intensity occurring in March 1918, March 1908, April 1947, and March 1916. The 1904 flood outline is shown on Plates H-17 and H-18. Smaller floods have occurred at more frequent intervals with minor flooding at lower profiles occurring almost annually.

(3) Metropolitan Lansing, a city complex of 170,000 people in 1960, is centered at the confluence of the Grand River and its tributary the Red Cedar River. There are 7.5 miles of highly developed flood plain within the city along the Grand River and 6.5 miles of developed flood plain along the Red Cedar River. These flood plains, as all others, have a history of flooding to varying degrees.

(4) No significant flood protection works have been constructed within the area to date. A low levee with a limited relief pump capacity has been constructed along the north bank on the Red Cedar River between the C. & O. Railroad and Kalamazoo Street, but this system is effective only against the more frequent small floods. Michigan State University in East Lansing is reported to have floodproofed all of its vulnerable structures for floods to the height of the April 1947 flood. East Lansing's new sewage treatment plant has its own protective levee which is reported to protect the plant from floods up to the magnitude of the April 1947 flood. The authorized (1955) plan called for a diversion channel and channel excavation which would protect all of Lansing, East Lansing, and Lansing Township. In this current basin-wide study of flood control, local flood protection for Lansing and vicinity was restudied as an alternative to and in conjunction with possible reservoir protection.

b. Flood problems. Major flooding at Lansing and vicinity occurs along the Grand River and its tributary, the Red Cedar River, within the boundaries of Lansing and East Lansing, and of Lansing Township, located between these two communities. Vacant lowlands upstream and downstream from these urban areas are also inundated during even minor floods, but only a few scattered cottages and residences are damaged from flooding in these outlying areas. Flooding along the Grand River, in general, commences from downstream of the Moores Park Dam and extends along both banks of the river through a congested residential, industrial, and commercial section, immediately adjacent to the heart of the city of Lansing, downstream to the Seymour Street bridge. From the Seymour Street bridge downstream to Delta Mills the lowlands are inundated by flooding, but only a few scattered industries and residences suffer flood damages. The inundated area along the Grand River through the city of Lansing is rather narrow in width, as the valley in this area is flanked by gradually sloping banks 30 to 40 feet in height. However, this valley is extensively developed and even minor inundations impose serious handicaps on the industries in the area. Flooding along the Red Cedar River commences generally in the vicinity of Michigan State University in East Lansing and extends downstream through Lansing Township, along both banks, to the River's confluence with the Grand River in the city of Lansing. Major damages in this section occur to the residential area along the right bank between Kalamazoo Street and the C. & O. Railway bridge, a stretch of about 50 city blocks. Downstream of this area, below the Pennsylvania Avenue bridge, extensively developed industrial areas are affected. Flood stage, discharge, and damage curves for Lansing and East Lansing are shown in Figures H-8 and H-9.

Table H-15 indicates the location, extent and general character of areas flooded by the April 1947 flood. It is estimated that the stage during the 1904 flood was about 2-1/2 feet above the 1947 flood, adding about 20 percent to the total area inundated and increasing considerably the damage to those areas because of greater and longer inundation. The damage estimates used for this report are based on the April 1947 flood, as it is the only flood for which complete damage data are available. Values of homes in the flooded areas range from low to above average. Some of the homes, especially along the Red Cedar River, have deteriorated in value because of their location in a flood hazard area. Practically all of the homes have basements which are flooded frequently. Basements of many homes in areas adjacent to this frequently inundated area are flooded during major floods because of the inability of drains to function properly during high river stages. In those downtown business districts adjacent to the Grand River there is appreciable damage through loss of stock stored in basements, and loss of wages, business, and production. Because of the early spring occurrence of the 1947 flood, there was practically no damage to agriculture lands and crops.

c. Average annual damage computations

(1) Damages that would result from occurrences of two hypothetical floods or from recurrence of the 1947 flood stage are shown in Table H-16 and H-17.

(2) In the decade between the old and current flood damage studies two significant changes have occurred. There has been both a gain and redistribution of potential damages within the area. In relative terms there has been a slight lessening of potential flood damages along the Grand River and an increase of potential damage within the Red Cedar River's flood plain. A slow decline in the utilization of the Grand's narrow flood plain has taken place as the city has developed. Considerable development, mostly commercial and institutional, has taken place within the Red Cedar's broad flood plain. The newer buildings are either located on higher ground, located on the upper limits of the flood plain, or floodproofed for the smaller floods. Only the larger floods will damage these newly developed structures.

(3) A second and probably more important change is in the flood discharge-frequency relationship assigned to the city. In the light of additional stream flow records and a basin-wide look at flood discharge frequencies and publishing of the results as "The 1962 Regional Flood Frequency Study", new flood frequency relationships were developed and adopted for this area.

(4) As a result of these recent studies, average annual damage estimates have been reduced from $385,000 to $54,300 at Lansing and increased from $170,000 to $241,600 at East Lansing.

TABLE H-15

APRIL 1947 FLOOD AREAS IN LANSING & VICINITY

Flood Area (Section)	Limits of Inundated Area	Area Inundated - Acres: Residential	Commercial	Industrial	Parks and Schools	Farm	Vacant	Totals
(a) East Lansing	C. & O. Ry. to East City Limits	145.1	6	4	162.8	82.5	152.4	552.8
(b) Red Cedar-Sycamore Creek	Junction to C. & O. Ry.	22.4	5	35	94.8	15.2	317.5	489.9
(c) Moores Park	Grand River above Junction	-	4	8.9	9.6	-	19.4	41.9
(d) Central	Junction to North Lansing Dam	11.5	12	30.4	-	-	16.2	70.1
(e) N. Lansing	North Lansing Dam to City Limits	11.7	4	6.9	-	-	83.8	106.4
(f) Downriver	Below City Limits to Delta Mills Bridge	-	-	-	-	169.8	162.3	322.1
	TOTALS	190.7	31.0	85.2	267.2	267.5	751.6	1,593.2

TABLE H-16

FLOOD DAMAGE SUMMARY - LANSING, MICHIGAN

RIVER: Grand
RIVER MILE: 148.7
INDEX POINT: N. Grand River Ave. Bridge (USGS gage)

	Hypothetical flood	Hypothetical flood	1947 flood
1. Flood stage (USGS elev.)	833.2	829.4	822.4
2. Exceedence freq. (percent)	.04	.19	2.5
3. Discharge (cfs)	45,000	30,000	16,400
4. Computed residential damages			
a. Units	1,157	861	225
b. Damages	$2,418,660	$1,377,820	$86,327
5. Computed business damages			
a. Units	350	325	109
b. Damages	$10,063,255	$5,721,897	$344,805
6. Other Damages	$ 2,947,232	$1,721,597	$ 45,742
7. Totals			
a. Units	1,507	1,186	334
b. Damages	$15,429,147	$8,821,314	$476,874
8. Average annual damages - (February 1960 price level)		$54,300	

TABLE H-17

FLOOD DAMAGE SUMMARY - EAST LANSING, MICHIGAN

RIVER: Red Cedar
RIVER MILE: 6.5
INDEX POINT: Farm Lane Bridge (USGS Gage)

	Hypothetical flood	Hypothetical flood	1947 flood
1. Flood stage (USGS elev.)	843.3	839.5	835.9
2. Exceedence freq. (percent)	0.01	0.2	3.2
3. Discharge (CFS)	15,400	10,300	5,920
4. Computed residential damages			
a. Units	2,588	2,085	772
b. Damages	$5,878,158	$3,606,249	$564,959
5. Computed business damages			
a. Units	152	148	65
b. Damages	$11,296,130	$4,826,425	$323,364
6. Other damages	$ 3,331,772	$2,127,877	$165,884
7. Totals			
a. Units	2,740	2,233	837
b. Damages	$20,506,060	10,560,551	$1,054,207
8. Average annual damages (February 1960 price level)		$241,600	

Flood damages applicable to Lansing and to East Lansing are based on an arbitrary division line where the Chesapeake & Ohio Railroad Bridge crosses the Red Cedar River. Flood damages upstream from this point are included in the East Lansing figures.

d. <u>Solutions considered</u>

(1) A full range of local flood protection schemes was tested. Upstream reservoir schemes, levees, and floodwalls were considered but discounted as not practical in the Lansing area. A channel improvement scheme was the obvious approach; the problem was to determine its location and scale. The authorized, published plan was considered the upper limit of development for Lansing and vicinity. One approach used was to scale back this plan. Another approach used in studying the area was to attempt to match the downstream effect of the Red Cedar reservoirs with channel improvements. These plans were supplemented by other plans (for example: modifying the bridges and their approach sections but not changing the channel). Another considered plan was a shallow channel improvement including widening most of the Red Cedar's bridges. This plan was considered with and without a diversion channel. After due consideration of all plans with regard to their physical potential, their benefit potential, and their cost, it was judged that a plan protecting the entire city be studied in detail. Each plan was hydraulically tested.

(2) The most practical plan of improvement for the Grand and Red Cedar Rivers at Lansing and vicinity is based on a combined design discharge of 25,000 second-feet, which is two percent greater than the reported maximum discharge of the record 1904 flood and 50 percent more than the April 1947 flood discharge. At the stage resulting from this design flood the channels would have a minimum design freeboard of two feet. With the exception of one or two local areas, for which levees would be provided, the channels would carry a combined flood discharge of 30,000 second-feet with only minor surface water inundation and limited backwater through sewers and seepage into basements. The principal features of this proposed plan of improvement are described below and illustrated on Plate H-19.

(a) The existing Red Cedar River channel would be widened, deepened, and straightened from below the College Dam on the Michigan State University campus in East Lansing to its confluence with the Grand River in Lansing to provide flood flow capacity of 8600 cfs as far as Sycamore Creek and thence 11,000 cfs to the Grand River, a total distance of about five miles, approximately as follows:

<u>1</u>. Provide an unlined earth channel with about 70-foot bottom width, 1-on-4 side slopes, 16-foot design depth, and 1.5-feet-per-mile gradient extending for 17,500 feet from the College Dam to the confluence with Sycamore Creek. The upper end of this design channel is to be sloped upward to meet the existing bottom grade at the dam. The restricted openings through the Chesapeake & Ohio Railway bridge (College spur) and Harrison Road Bridge are to be riprapped to permit greater velocity without excessive scour; still smaller openings of the Athletic Bridge on the college campus and the Kalamazoo Street bridge are to be paved with reinforced concrete to prevent scour from high velocities during flood flows.

2. Provide a channel with 110-foot bottom width, 1-on-4 side slopes, 17-foot design depth, and 1.0-foot-per-mile slope extending from the mouth of Sycamore Creek to the Grand River, a distance of 8000 feet. Openings through existing railroad and highway bridges in this reach should be riprapped to prevent erosion.

3. Clean out and straighten that portion of the Sycamore Creek within Lansing city limits to provide better flow conditions.

(b) The existing Grand River channel from its confluence with the Red Cedar River in Lansing would be widened, deepened, and straightened downstream to a point about two-thirds of a mile below the North Waverly Road bridge, a total distance of six miles, to provide a flood flow design capacity of 12,400 cfs, including 1400 cfs from the Grand River above its junction with the Red Cedar River, approximately as follows:

1. Provide, by means of a general cleaning-out, a channel with a bottom width of about 110 feet, 1-on-3 side slopes, 17-foot design depth, and 1.5-feet-per-mile gradient extending from the Grand-Red Cedar River junction downstream to the Shiawassee Street bridge, a distance of 5000 feet. Existing side slopes in this reach above the cut will not be disturbed except as noted below and will be paved with about 18 inches of dumped riprap to reduce bank scour. In the vicinity of the new Main Street bridge it is desirable to widen the channel and to provide 1-on-3 side slopes paved with 18 inches of dumped riprap to prevent bank scour.

2. Provide an unpaved earth channel of 130-foot bottom width, 1-on-4 side slopes, 17-foot design depth, and approximately 1.0-foot-per-mile gradient extending from the Shiawassee Street bridge downstream to the North Lansing Dam, a distance of 3100 feet. Existing channel conditions in this reach permit the use of this type of design channel without extensive channel excavation and real estate costs.

3. Provide an unlined earth channel with a 130-foot bottom width, 1-on-4 side slopes, 16-foot design depth, and 1.3-feet-per-mile gradient extending from the North Lansing Dam downstream to the Seymour Street bridge, a distance of 2600 feet.

4. Provide an unlined earth channel having 280-foot bottom width, 1-on-4 side slopes, 16-foot design depth, and 0.35-foot-per-mile gradient extending from the Seymour Street bridge downstream to about two-thirds of a mile below North Waverly Road Bridge, a distance of 21,000 feet. Because of the undeveloped nature of the river banks in this area the design of this portion of the channel has been flattened and widened to permit a reduction in grade so that the floodwater will blend into the backwater from the natural channel downstream as soon as possible.

(c) A bypass channel with a design capacity of 13,000 second-feet will be provided between the Grand River in the vicinity of Millett and the Grand River in the vicinity of Delta Mills, a distance of six miles, as follows:

1. Provide an unlined earth channel with 65-foot bottom width, 1-on-4 side slopes, 20-foot design depth, and 1.5-feet-per-mile gradient extending for 27,600 feet from the Grand River diversion works to a drop structure. A reinforced concrete head weir and drop structure would be provided at the upper end to permit adequate transition of flow from the pond above the diversion dam to the cutoff channel.

2. Provide a reinforced concrete paved drop structure with adequate stilling basin to permit a design water surface drop of 18.4 feet and a channel bottom drop of 12.4 feet.

3. Provide unlined earth channel of 150-foot bottom width, 1-on-4 side slopes, 14-foot design depth, and 1.8-feet-per-mile gradient for a distance of 4300 feet from the drop structure to the Grand River in the vicinity of Delta Mills.

(d) These channel enlargements, involving 9,621,000 cubic yards of excavated materials, are based on the following design criteria:

1. Manning roughness coefficient:

a. Earth and riprapped channels = 0.030

b. Concrete-lined channel = 0.015

2. Maximum velocities the various channel sections are to be subjected to:

a. Earth channel - 4 feet per second

b. Riprap channel - 5 feet per second

c. Through riprapped bridge - 6 feet per second

d. Through concrete paved bridge - 8 feet per second

3. The design depths for these channels have been established to require the least changes in existing bridge foundations, piers, and abutments. Borings and subsurface explorations indicate that this excavation will be entirely in overburden. However, it is possible that there will be a very limited amount of shallow excavation in soft shale near the bottom of the heaviest cut in the cutoff channel.

4. Riprap channel at critical points to reduce scour.

5. Pave channel with eight inches of reinforced concrete and adequate subgrade at critical points to reduce scour.

6. Construct seven new highway bridges and four new railroad bridges over the Grand and Red Cedar Rivers and diversion channel.

7. Reinforce substructure, piers, and abutments on ten highway and five railroad bridges over the Grand and Red Cedar Rivers.

8. Elevate two highway bridges on the Grand River to provide adequate underclearance and relocate approximately one-quarter mile of highway for the diversion channel.

9. Remove existing buildings and structures from right-of-way.

10. Clear brush and shrubbery from right-of-way.

11. Seed side slopes and right-of-way along the entire proposed channel.

12. Strengthen and extend the low earth levee along the right bank of the Red Cedar River in Lansing Township.

13. Construct a diversion dam across the Grand River in the vicinity of Millett with the top at an elevation of 860.0 feet. This structure would have one tainter gate 16 feet high by 25 feet wide, reinforced concrete foundation slab, abutments, core wall and wing walls, baffle piers, and an "Ogee" section concrete spillway, 467 feet in length, with stilling basin and steel sheet pile cutoff walls, and an earth fill non-overflow section at each end. The sill of the gate section would be at elevation 820.0 and the crest of the spillway would be at elevation 850.0. At low flow stages in the river, the tainter gate would remain open, permitting complete discharge down the existing channel. The crest of the Moores Park Dam, located about three miles downstream, is at elevation 832.2. As a Grand River discharge of about 4400 second-feet is reached, the tainter gate would be closed and water would pond above the diversion dam to the elevation of the crest of the tainter gate, 836.0, which is also the crest elevation of the diversion weir, and the floodwaters would be diverted down the cutoff channel. As the flow increases the gate would be opened so as to maintain the pool elevation at the top of the gate. At the design discharge, 13,000 second-feet would be diverted down the cutoff channel and 1400 second-feet would pass through the tainter gate and thence down the existing channel. The backwater elevation above the diversion structure would be at the same elevation as with comparable discharges in the existing channel without diversion. It is considered desirable to provide a concrete spillway section to protect the diversion dam against overtopping by floods equal to the maximum probable flood. At a Grand River discharge of this magnitude (62,000 second-feet), flow down the cutoff channel would be 36,000 second-feet, through the open gate and over the spillway section would be 26,000 second-feet, and the water elevation at the dam would be 5.5 feet below the top of the non-overflow section.

14. Make alterations to existing water, gas, sanitary and storm sewers, water intakes, and electric and telephone lines as necessary for the new and improved channels.

e. Economic analysis

SUMMARY, ESTIMATE OF COST
(In 1954 Dollars)

Item	Contract	Contingencies	E&D	S&A	Total
Lands right-of-ways etc.	$ 679,000	$ 170,000	$ 85,000	$ 60,700	$ 994,500
Bridges, roads & utility relocations etc.	1,616,000	404,000	202,000	144,430	2,366,430
Construction excavations dam, riprap, etc.	6,323,000	1,581,000	790,400	565,136	9,259,500
TOTAL	8,618,000	2,155,000	1,077,400	770,200	12,620,600
TOTAL Converted to dollars.*					$16,347,000

* Adjustment based on Engineering New Record index (1960)

The total cost for the proposed channel improvement and channel diversion is estimated at $16,347,000. The Federal first cost share would be $12,167,000 and local interest would bear $4,180,000 of the first cost. Comparing the cost of this plan to the 1956 estimate, about $1,000,000 in new bridge costs have been added to service the growing city. The remainder of the difference is accounted for by a 32 percent rise in construction cost between 1954, the index year used in the report,and 1969, the the index year used in this study. When the cost of the project is amortized over fifty years at 4-5/8 percent interest, the average annual cost is $873,500. In addition to direct flood protection for existing conditions, both higher utilization of lands and the availability of land not usable before will provide an additional $46,000 in annual benefits. Annual benefits for the entire Lansing area will total $341,900.

f. Summary of investigation. Flood conditions are experienced at Lansing and vicinity nearly every year. These conditions, however, are normally limited to vacant lowlands located upstream and downstream of the urbanized areas with serious flood conditions existing for floods of 50-year recurrence frequency. Average annual damages amount to $54,300 and $241,600 for Lansing and East Lansing respectively. Several plans of flood control protection were studied. The most practical plan of improvement

consists of channel improvements in the Grand and Red Cedar Rivers, and construction of a diversion channel for high Grand River flows. This improvement plan would provide protection against the 1904 flood of record. Detailed economic studies indicate that average annual costs associated with the plan of protection would total $873,500. The resultant benefit-cost ratio is 0.40; hence, the flood control project for Lansing and vicinity is not feasible and not recommended. These recent studies do not support the authorized project for the Lansing area, since average annual damages have been reduced as a result of using the Grand River Regional Frequency Study of 1962, while average annual costs have increased from $459,440 to $873,500 with 1954 as the base price year, and interest rates were changed from 2-1/2 percent in 1954 to 4-5/8 percent in 1969.

22. DIMONDALE. The Dimondale Village President has stated that no damage occurred in the village from the 1947 flood. All building developments at Dimondale are located on high ground. Wilson Brothers' Dimondale Mill, which as late as 1950 employed two men to operate the facility, was forced to shut down operations due to high tailwater elevations downstream of the dam. In 1947 and 1948 the Dimondale Dam, owned by the city of Lansing, was in danger of washing out. Several men sandbagged the dam until the threat had passed. There was no preliminary investigation of a protection scheme at the village of Dimondale because of the minor damages and negligible benefits to be derived.

23. EATON RAPIDS

a. Description of the area

(1) Eaton Rapids is located in the southeastern section of Eaton county, approximately 18 miles south of Lansing. The city lies on both banks of the Grand River, including four islands within the city limits between river miles 180 and 182. The Grand River at Eaton Rapids drains an area of about 661 square miles. The four small islands located within the city limits have been formed at the junction of Spring Brook with the Grand River. This small tributary (84 square miles of drainage area) flows for about 20-1/2 miles northward to join the Grand River in the heart of the downtown business area. One minor creek, unnamed and of little significance, joins the Grand River within the city limits from the east as a feeder to the main stream. The neighboring countryside around Eaton Rapids is representative of the glaciated areas of lower Michigan, gently rolling hills (moraines) and outwash plains. Kames, composed of sand and gravel capped by clay, rise 20 to 50 feet above the level of the plain. Kettles, roughly circular depressions as much as 50 feet below the level of the plain, are typically swamps and bogs.

(2) Eaton Rapids has shown a large increase in population from 1940 to date. As of the 1960 census, the total number of residents in the city was 4052 persons, a 15-1/2 percent increase over the previous decade and a 32 percent increase from the 1940 figure of 3060 persons. Eaton Rapids is located in one of the heaviest crop-producing districts in the state. The most important crops are small grains such as field corn,

wheat, and barley. In addition to revenue received from local farming enterprises, the city also derives a small income from the sand and gravel industry. The manufacture of dairy products is still a prosperous industry, but a long established woolen mill has ceased operations. Also, Union Camp Company, formerly Raisin River Paper Company, closed its Eaton Rapids plant when its new plant at Kalamazoo was completed in August 1966. Seventy-five retail establishments, employing 330 persons, provide personal and mercantile services.

(3) A USGS stream gaging station is on the Grand River at river mile 178 near the city of Eaton Rapids. It is located in NE1/4, section 26, T2N, R3W, on the right bank 400 feet upstream from the bridge on Petrieville Highway, two miles northeast of Eaton Rapids, 2-1/2 miles downstream from Spring Brook, and 25 miles upstream from the Red Cedar River confluence. The drainage area at the gage is 661 square miles. Continuous records are available from October 1950 to date. Also, there is a U. S. Weather Bureau staff gage in Eaton Rapids on the west abutment of the West Hamlin Street footbridge.

(4) The city of Eaton Rapids has developed its municipal water supply from shallow wells drilled into 50 to 70 feet of glacial drift and from deeper wells extending 300 feet below the ground surface into bedrock. The water is treated to remove iron salts only. Storage is provided by means of a 250,000-gallon elevated tank. The sanitary system consists of a combined sanitary and storm sewerage system which is designed to carry one million gallons per day. Settling tanks, chlorination by gas, digesters, and sludge beds make up the sewage-treatment plan which has been judged by State authorities to be satisfactory and adequate for future expansion. Public utilities in the city consist of one municipal and one privately owned electric power plant and one privately owned gas plant.

(5) Fifteen bridges cross the Grand River and Spring Brook between Petrieville Road downstream from Eaton Rapids and Smithville Road upstream. Two of these are railroad trestles, two are State highway bridges, and the remainder carry both pedestrian and vehicular traffic. Two dams in and near Eaton Rapids impound water for generation of electric power. Transportation facilities at Eaton Rapids are limited in number, but appear to be adequate for the needs of the community. The New York Central Railroad provides rail service between Lake Michigan and Lake Erie ports. Passengers may board the Chesapeake and Ohio Railway lines at Lansing, and the Grand Trunk Western Railroad at nearby Charlotte. Three State highways enter Eaton Rapids: M-50, running generally east-west, connects Monroe and Jackson with Grand Rapids and Muskegon; M-99 provides access from Lansing south to the Ohio Turnpike; and M-188, a relatively short highway, runs between Eaton Rapids and the V.F.W. National Home near Kinneville to the southeast.

b. Flood problems. Flood damages in the city of Eaton Rapids are periodically experienced, principally in the downstream business district, located on a large island at the junction of Spring Brook with the Grand River. About 25 city blocks, containing 45 to 50 businesses and 50 to 60

residences, are subject to inundations to depths of two feet or more by the larger floods. Flood damages have mainly been recorded as basement damages, except for a few instances of first floor flooding in the down-town business establishments. During the 1947 flood, 50 homes and 33 commercial buildings were reported to have water in their basements, and eight homes and 16 business buildings were reported to have experienced first floor flooding. Flood stage, discharge, and damage curves relationships are shown in Figure H-10.

c. Average annual damage computations. Table H-18 summarizes the damages that would result from recurrences of the 1943, 1947, and 1956 floods. Plate H-20 shows a 1947 flood outline.

d. Solutions considered. Because of the relatively flat topography of the terrain near Eaton Rapids and the location of the town mainly on islands, the control of flooding presents a somewhat complex problem. Consideration was given to increasing the channel capacity by widening, deepening, and straightening. Controlling of flood flows solely at Eaton Rapids, by a system of reservoirs, was studied on a basin-wide scale. It was apparent from a look at the reservoir construction costs that this type of solution (considering only flood control purposes) could not be justified. However, the project formulation studies considered potential Eaton Rapids flood control benefits along with benefits in other communities for both single-purpose and multi-purpose reservoir protection plans. The geography of Eaton Rapids, with the two streams and the millrace channel, is such that levee lines would be of considerable length and therefore costly. The business district is located on what can be considered a low island. Most of the residential development, except for isolated cases, is located on higher ground. The entire business district would have to be surrounded by a levee or a flood wall system. The street openings would have to be protected or blocked off; also, an extensive interior drainage system would be required. Other areas of the city would also need protection by a similar program of levees and interior drainage systems if a high degree of protection were required. The cost of this type of plan would be extremely high when compared to the benefits to be gained; however, if an adequate system were provided, nearly all flood damage could be prevented. Another plan considered the feasibility of modifying the existing power diversion dam that is located just upstream of State Street. This plan called for the modification of the existing fixed crest dam to a gated control structure. The gates would be open during flood flows to reduce the upstream stage and to reduce flows going into the millrace. Overland flooding would be reduced, but flooding from sewer back-up would not change. The benefits would be limited to reduction of overland flooding in the business district, with benefits estimated to be $12,741 for the 1947 flood. Still another plan given consideration was improving the outlet for Spring Brook and closing off Grand River inflows. This plan assumes that the bulk of overland flooding comes from Spring Brook and not from the Grand River. During peak Grand River stages, flows into Spring Brook via the millrace reach a maximum of about 700 cfs, increasing the String Brook peak by about 20 percent. The high Grand River

stages also reduced the outlet capacity for Spring Brook flood flows. A two-step scheme was considered to solve the problem:

Step 1: Construct a closure structure across the millrace and block Grand River flows from entering during high flood stages.

Step 2: Increase the outlet capacity of Spring Brook by constructing additional outlet conduits.

It was estimated that a new three-barrel outlet structure, with an additional 600 cfs capacity, would be sufficient to keep Spring Brook backwaters below the flood damaging stage. This plan was found to stop most overland flooding at a minimum cost; however, it would not stop the sewer back-up damage. Potential benefits would be limited to elimination of overland flooding damages. The benefit-cost ratio indicates that this is not an economically feasible solution. It was concluded that control to keep the Grand River flow below the 865.0-foot elevation by an upstream reservoir or the diversion scheme, although not economically feasible, would be the only physically acceptable solution to the Eaton Rapids flood problem.

e. Economic analysis. Reservoir studies are presented in Section V. The diversion plan calls for diverting the Grand River from the Smithville Dam backwater pool across a large meandering bend in the river and into the Grand River about one mile downstream from Eaton Rapids. The diversion channel, shown on Plate H-21, Plan of Protection, would run north from a new gated control structure adjacent to the backwater pool at the Smithville Dam. The channel would be 12,000 feet long and would have a 50-foot bottom width and 2:1 sideslopes. The design slope for the stream bottom was chosen to be 0.00025, starting at an elevation of 857 feet at the dam. Costs were computed for a gated entrance structure to be required at the head of the channel since the pond level will fluctuate more by the operation of the dam than by flood flows. Necessary energy dispersion structures were included at both ends of the channel. Two county roads, Plains Highway and Barnes Highway, will require new bridges. The proposed channel will handle up to a maximum discharge of 6200 cfs. Smaller channels were considered but the cost reduction did not seem to warrant the reduction in protection.

SUMMARY, ESTIMATE OF COST
Eaton Rapids

A. Non-Federal Cost

Item	Contract	Contingencies	E&D	S&A	Totals
Lands	$ 26,400	$ 6,600			$ 33,000
Bridges	312,000	78,000			390,000
Subtotals Non-Federal	$ 338,000	$ 84,600			$ 423,000

B. Federal

Item	Contract	Contingencies	E&D	S&A	Totals
Excavation	$1,191,400	$ 298,000	$148,900	$106,500	$ 1,744,800
Fill	791,100	198,000	98,900	70,720	1,158,700
Structures	95,500	23,900	12,000	8,500	140,000
E.&D.			$259,800		
S.&A.				$185,800	
Subtotal Federal	$2,078,000	$ 519,900	$259,800	$185,800	$ 3,043,500
Total First Cost	$2,416,400	$ 604,500	$259,800	$185,800	$ 3,466,500
				TOTAL	$ 6,933,000

Annual Cost Summary

$ 423,000 x .0516	=	$ 21,800
3,043,500 x .0516	=	157,000
		$178,800
	SAY	178,800
Operation and maintenance	=	2,500
Total		$181,300

Based on a review of the updated damage survey data, the average annual damages for Eaton Rapids are estimated to be $14,290, based on 1960 prices. The index point for this damage estimate is the U.S. Weather Bureau Gage. The preliminary estimate of the diversion channel construction cost is $3,466,500. The average annual cost is $181,300 based upon a 50 year financing period and a 4-5/8 percent interest rate. Annual operation and maintenance costs are estimated to be $2,500. A comparison of the potential benefits to costs, gives a benefit-cost ratio of 0.08 to 1.0.

TABLE H-18

FLOOD DAMAGE SUMMARY - EATON RAPIDS, MICHIGAN

RIVER: Grand
RIVER MILE: 180.6
INDEX POINT: USGS Gage

	1947 Flood	1943 Flood	1956 Flood
1. Flood stage (USGS elev.)	862.4	861.7	860.4
2. Exceedence freq. (percent)	1.5	3.75	11.35
3. Discharge (cfs)	6,620	6,000	4,650
4. Computed residential damages			
a. Units	58	39	25
b. Damages	$36,010	$19,530	$ 8,480
5. Computed commercial, industrial and other damages			
a. Units	49	32	26
b. Damages	$44,302	$23,712	$17,743
6. Totals			
a. Units	107	71	51
b. Damages	$80,312	$43,242	$26,223
7. Average annual damages (February 1960 price level)		$11,723	

f. Summary of investigation. Eaton Rapids has a flood damage problem. The problem may be corrected by several schemes; the best plan appears to be a diversion of Grand River flood flows around the town. Because of the relatively small benefits to be derived, which result in unfavorable benefit-cost ratio, it was concluded that no further study of a flood control project at Eaton Rapids is justified at this time.

24. JACKSON. Recent floods in the Jackson, Michigan, area have been minor in nature. None of consequence have been reported along this reach of the Grand River since the 1930's, when local interests improved the Grand River at Jackson. Although some local flooding does occur off-river as a result of inadequate storm drainage, the situation is being remedied. The lakes and swamps upstream from Jackson serve as natural controls for runoff, temporarily storing the water as it collects and releasing it slowly over a long period of time. Jackson's location in the headwaters of the Grand River basin is favorable, but a major flood could be experienced if a rare intense storm, or a combination of several severe storms, occur in the area. In April 1950 approximately 1.81 inches of rain fell on the saturated ground, and catch basins in the city, blocked by debris, caused flooded streets in many areas. Overloaded sewers also caused flooding in basements of hundreds of houses. During this storm the Grand River reached the second highest level shown in the records of the USGS gage at the sewage treatment plant. The highest level of record, elevation 913.5 feet, occurred 25 June 1937. The Superintendent of Public Works stated that if the Grand River started to overflow the retaining walls at the dam, impounding water within the city limits, the lower flood gates in the spillway would be opened. At this time, the water would be roughly seven feet over the covered river conduit in the city, and it was estimated that opening the gates at the dam would add about one foot to the river stage. In April 1947 Jackson recorded a 3.17 inch rainafall that caused flooded streets and basements from clogged catch basins and overloaded sewers. An interview with the City Engineer revealed that 300 homes in the township area were flooded. No damage, however, was caused by high Grand River stages. Commercial damage was approximately $2,000 due to flooded basements caused by catch basin and sewer conditions. This appears to be a local drainage problem rather than a Grand River flooding problem. Because of the relatively minor flood problem which exists from the Grand River at Jackson, no local protection plans were studied for flood control. The character and extent of the upstream watershed and the controls affecting flows through Jackson are such that flood conditions would have slight chance of occurrence in the City.

25. MASON. The highest and most severe recent flood recorded on Sycamore Creek at Mason occurred in 1947. At that time, Sycamore Creek was at its highest level since a similar 1918 flood recalled by residents. The West Elm Street bridge was washed out and flood waters threatened the Ash Street bridge. Fearing the water would wash out a Consumers Power Company electric substation in Mason, the area around the structure was sandbagged. Ten to twelve houses on North Lansing and West Maple Streets in Mason were completely surrounded with water. The 1947 flood ripped away 200 feet of

New York Central Railroad track near the intersection of Park and Elm Streets. Based on the flood damages experienced that year, average annual damages were estimated to be $21,800. Yet, as far as local interests are concerned, no serious flood problem exists at the city of Mason except in a few isolated areas. A 16 June 1958 letter from the City Engineer stated: "The writer has been a resident of Mason for the past 51 years and has never considered Mason a a problem area in the matter of floods, except in very small areas." After no reply was received to a November 1964 letter sent to the Mayor of Mason asking whether the city desired a continuation of the flood control study as part of the Grand River Basin Comprehensive Study, it was decided that flood control studies should not be undertaken for Mason.

26. OTHERS. In addition to the above communities reporting flood damages, Hastings on the Thornapple River; Muir, Maple Rapids, and Ovid on the Maple River; and Okemos, Williamston, and Fowlerville on the Red Cedar River have experienced occasional minor flood damages. These areas were not studied in detail on the premise that such studies were not warranted.

SECTION III

AGRICULTURAL FLOOD DAMAGE STUDIES

27. GENERAL. This is a summary of the preliminary evaluation of agricultural flood damages along the main stem of the Grand River and the Red Cedar River. The study was conducted to determine the extent and distribution of flood damages in the sectors between the urban damage centers along the main stem of the Grand River and along some of its major tributaries. The first objective was to determine, by use of readily available data, if significant damages occur. If so, then a detailed study program would be developed to evaluate the precise damages. It was decided to study the Red Cedar River as representative of the conditions to be found on the major tributaries.

28. AVAILABLE DATA UTILIZED. The entire basin had been studied in the early 1930's in preparation of the Corps of Engineers' "308 Reports". One element of this report was the preparation of a series of topographic maps of the flood plain area. This mapping covers the valley of the main stem in detail from the city of Jackson to the city of Grandville and also the lower reaches of all the major tributaries. The maps also indicated the current land-use patterns.

a. A 1959 Corps of Engineers document titled "Interim Survey Report on Major Drainage and Flood Control for Portage River, Michigan" was also utilized. This report was prepared jointly by the Corps of Engineers and the Department of Agriculture's Soil Conservation Service for the Portage River sub-basin, an agricultural area in the upper Grand River basin.

b. In addition to the above two published reports, other data collected on the Basin for other purposes and reports were utilized. These included the 1962 Regional Flood Frequency Study, the numerous stage-discharge relationships developed for gaging stations and other index points, and a flood profile of the highest elevation reached during the 1947 flood along the main stem. Recent Department of Agriculture aerial photograph mosaics available for all counties within the Basin were utilized to establish current land-use patterns and to note changed conditions.

29. METHODOLOGY. Initially, land-use patterns were identified from aerial photographs and color codes on the "308" topographic maps. Three land-use categories were established for simplicity; productive agricultural lands, non-productive agricultural lands, and non-agricultural lands. The flooding outline for three floods was next delineated--the 1947 flood outline and two hypothetical flood outlines: a flood two feet higher than the 1947 flood, and a flood five feet below the 1947 flood. The main stem was then subdivided into reaches or sections that could be referenced to one of the existing index points, usually a gaging station having an available rating curve. Inundated area by land-use category was estimated for each flood by use of stage - inundated-area relationship curves.

Crop values and other agricultural relationships were developed for the entire reach under study based on data found in the 1959 Portage River report. Average crop loss values in dollars per unit area for each land-use were established. Average annual potential damage values for each of the selected river reaches were next determined by combining values represented by the stage-area curve, the stage-discharge curve, the discharge-frequency curve, and unit prices. The results were analyzed by individual reach and then summed.

30. RESULTS. The study's findings are presented in Table H-19. Damage values based on three different frequency relationships were developed. The figures found under column "Corrected to Seasonal Frequency" are considered most appropriate for use, but the values do not differ significantly.

31. INTERPRETATION OF RESULTS. This study clearly illustrates that flood damages to agricultural lands located along the main stream between the urban damage centers do occur but are not significant. The magnitude of the damage is small compared to average annual cost for any protection plan. The validity of these results is further reinforced when the physical characteristics along the river are considered. In general, the flood plain is narrow in width and is seldom flat. Abrupt changes in grade away from the river are common. Floods usually occur in the late winter or early spring, before crops are planted; the flood plain, however, is not especially fertile and is usually not cultivated. There are few farm houses or other rural structures in the flood plain, and the damages are so small in dollar value and varied in location that they may be neglected in initial planning. However, they should not be overlooked when evaluating benefits for proposed projects.

TABLE H-19

AGRICULTURAL DAMAGES

REACH (Index Point)	RIVER MILES (Study Sector)	AVERAGE ANNUAL DAMAGES IN DOLLARS Based on annual frequency	Corrected to seasonal frequency	Corrected to monthly frequency
Grand River				
Comstock Park	43.0-53.4	2,530	1,670	1,870
Ada	53.4-66.0	4,080	2,690	3,020
Lowell	66.0-77.9	4,450	2,940	3,290
Ionia	77.9-97.8	9,900	6,530	7,330
Portland	97.8-127.0	1,250	830	920
Grand Ledge	127.0-146.0	160	110	120
Lansing	146.0-158.6	110	70	80
Dimondale	158.6-171.4	500	330	370
Eaton Rapids	171.4-216.0	2,050	1,350	1,520
Reach Total	43.0-216.0	25,030	16,520	18,520
Red Cedar River	6.5 to 21.0	1,460	964	1,080

TABLE H-20

ESTIMATED POTENTIAL FLOOD DAMAGE BENEFITS IN DOLLARS
BASED ON AVERAGE ANNUAL DAMAGES (1960 PRICE LEVEL)

Reduction in all Peak Flows passing damage Center resulting from Upstream Reservoirs (cfs)	FIVE MAJOR DAMAGE CENTERS IN THE BASIN				
	East Lansing	Lansing	Ionia	Lowell	Grand Rapids
0	$ 0	$ 0	$ 0	$ 0	$ 0
1,000	127,000	12,000	5,000	5,000	16,000
2,000	189,000	21,000	10,000	10,000	44,000
3,000	220,000	28,000	14,000	14,000	71,000
4,000	235,000	30,000	18,000	18,000	98,000
5,000	243,000	38,000	22,000	21,000	122,000
6,000	243,000	42,000	25,000	25,000	143,000
7,000	243,000	44,000	28,000	28,000	160,000
8,000	243,000	46,000	31,000	30,000	178,000
9,000	243,000	48,000	33,000	33,000	196,000
10,000	243,000	49,000	35,000	35,000	212,000
12,000	243,000	51,000	38,000	38,000	236,000
14,000	243,000	52,000	41,000	41,000	260,000
16,000	243,000	53,000	43,000	44,000	277,000
18,000	243,000	53,000	44,000	46,000	293,000
20,000	243,000	54,000	45,000	47,000	308,000
22,000	243,000	54,000	45,000	49,000	318,000
24,000	243,000	54,000	45,000	50,000	329,000
26,000	243,000	54,000	45,000	51,000	338,000
28,000	243,000	54,000	45,000	51,000	344,000
30,000	243,000	54,000	45,000	52,000	350,000
32,000	243,000	54,000	45,000	53,000	356,000
34,000	243,000	54,000	45,000	53,000	361,000
36,000	243,000	54,000	45,000	53,000	364,000
38,000	243,000	54,000	45,000	54,000	368,000
40,000	243,000	54,000	45,000	54,000	371,000

TABLE H-21
CRITERIA USED IN PRELIMINARY HYDROLOGIC SCREENING OF FLOOD CONTROL RESERVOIRS

1. A reservoir site had to control at least 75 square miles of drainage area. A minimum of about a 6 per cent control of flood flows for the major upstream damage center at Lansing would be realized by restricting the area controlled to this minimum.

2. Reservoir sites had to be situated upstream of damage centers being investigated.

3. It was assumed that the full reservoir capacity at maximum development size would be utilized for flood control storage.

4. Two different storm patterns were analyzed in determining reservoir effects on flood flows at the various damage centers. The April 1947 storm was selected for the Upper Grand River sub-basin, and the March 1948 storm was selected for the Lower Grand River sub-basin. Rainfall excess amounts of the two storms for the various subbasins were increased by two inches to provide a range of flows to determine the modifying effects of the various reservoirs schemes.

5. Those sites determined to provide beneficial hydraulic capabilities in controlling flood flows on an individual basis were combined and their resulting flood control effectiveness determined. Noting that Lansing and East Lansing are the major damage centers for which flood control protection is to be provided, it was considered applicable to assume that those reservoir schemes upstream of Lansing which had the most potential with regard to controlling flows past Lansing and East Lansing would also have the most influence on control of flows at damage centers downstream of Lansing.

6. When combinations of reservoir sites were investigated, the allocation of storage to the individual sites would be based on utilizing that site which had the greater economic potential to its best advantage, that is, the site with the lowest cost per acre-foot of storage was utilized to its maximum storage capability.

7. Those sites determined to be the best sites upstream of Lansing were combined with those sites which were considered to have the most potential downstream of Lansing. The best potential reservoir schemes located upstream of Lansing were determined by the effectiveness of controlling flood flows at East Lansing and Lansing. The best potential reservoir schemes located downstream of Lansing were determined by the effectiveness of controlling flood flows at Ionia, Lowell and Grand Rapids.

8. With adequate river stage and flood forecasting systems in operation, it was assumed that reservoir holdouts at the various sites could begin as early as 12 hours prior to the beginning of rainfall excess.

9. Antecedent conditions are considered to be similar to those which occurred during the 1904, 1947, and 1948 floods, that is, rather high base flows coincidental with the beginning of runoff excess. Reservoir schemes would not reduce river discharges below the base flow prevailing prior to the April 1947 flood at East Lansing and Lansing, or below the base flow prevailing prior to the March 1948 flood at Ionia, Lowell and Grand Rapids.

10. Variable release rates were used for each site and each flood so as to reduce flood stages to a minimum at all damage centers for a given storage capacity.

11. Graphical routings through reservoirs and stream reaches were used in determining the flood control effectiveness of preliminary schemes for Lansing, East Lansing, Ionia, Lowell, and Grand Rapids.

SECTION IV

FLOOD CONTROL RESERVOIR STUDIES

32. GENERAL. Reservoirs were studied for those instances where this method of flood control seemed reasonable from the standpoint of beneficial and hydrologic potential. The large number of potential reservoir sites (79) located within the Basin required the development of a well-defined screening technique. The screening technique developed for these studies is described in the following paragraphs.

a. Review of screening process. Single-purpose flood control reservoirs were ruled out only after economic and physical evaluations of each reservoir site. This process of elimination was used: first, those reservoirs obviously poor with respect to size and location were eliminated; then, the remaining sites were analyzed within their immediate sphere of influence using hydraulic and economic considerations; and finally, the more promising sites were investigated in greater detail. Scale of development for individual dam sites was checked by testing the hydraulic and economic characteristics of one to three different size impoundments. The effects of combinations of reservoirs were tested and evaluated in the same manner as the individual sites.

(1) Most of the flood damage reduction estimates and many of the hydrologic properties were calculated on a computer. Techniques used on the computer were comparable to manual techniques except that speed of computation was increased. This increased capacity was utilized to check all reasonable plans.

(2) Table H-20 illustrates the flood reduction benefits in dollars for a range of flood peak reductions at the five major damage (index) cities. These five cities suffer about 75 percent of the average annual damages within the Basin. Hence, flood control storage should be studied further when other single-purpose uses (which would share in the cost) are known and a multi-purpose project reservoir is considered.

33. AVAILABLE DATA. Shortly after the comprehensive planning study was started all available historical and technical data on the Basin was gathered, reviewed, and updated. Additional general information and special studies were initiated for anticipated needs. Most of this information was presented in a working paper, the "Grand River Basin Data Book". The more specialized data are generally available in working files and specialized technical publications. Abundant hydraulic and hydrologic data developed in the past or specifically prepared for this study aided materially in the reservoir screening process.

a. A Corps of Engineers inventory of 79 reservoir sites contained a tabulation of physical parameters for each site: dam site location, upstream drainage area, volume of impoundment and water surface area for specific elevations of impoundment, and, where possible, a cost estimate for various

heights of impoundment, based on a generalized earth-filled dam design. A regionalized flood frequency relationship for the entire Basin had been developed by the Corps of Engineers and adopted in 1962. Thus frequency relationships were available at all major urban damage centers and could be prepared for any other location within the Basin. Stage-damage relationships were available for all major flood damage centers previously identified. Hydraulic data were also available, including stage-discharge relationships at these damage centers and results of extensive flood and stream routing studies. As the reservoir study progressed, this initial data was checked and improved, and updated where necessary.

34. METHODOLOGY. Reservoirs usable as flood control impoundments were screened in the following sequence: (1) Rule out obviously unsuited reservoir sites, (2) Compute the flood peak reduction potential of each remaining reservoir and route the reduction flow effects to the downstream damage (index) cities, (3) Translate the flow reduction at each index city into a modified discharge-frequency relationship, (4) Calculate the potential benefits of each reservoir scheme with relationship to the index city, (5) Compare the average annual benefit for each reservoir scheme with the average annual cost necessary to provide the benefit, (6) Select for additional study those reservoirs with the better benefit-cost ratios, (7) Initiate more detailed technical analysis of the more favorable reservoir schemes, (8) Refine the selected dams' operational and structural designs, (9) Prepare new cost estimates for each reservoir site, (10) Repeat steps 2 through 5 for the refined plans, and (11) Recommend the feasible reservoir schemes.

a. Three screening techniques were used in these reservoir studies to ensure that no significant sites or combinations of sites were overlooked. The three techniques gave almost identical results. The first technique included ten weighted judgment criteria. A numerical score was computed for each site and the sites were ranked by their score from highest to lowest.

b. The second technique was for an engineer experienced in flood control investigations to make a site-by-site investigation. He recorded his comments as he proceeded, weighing each known fact. He thus picked the most desirable reservoir from each group of alternative sites and ruled out sites obviously not suited for flood control purposes. The selected sites were subjected to hydraulic testing and economic evaluation. When the results of the computations on the selected sites reflected any doubts on the reviewer's judgment, the affected sites were again individually tested.

c. In the third technique the sites were screened, using solely hydrologic effectiveness in reducing flows at the downstream damage centers. This was followed by an economic analysis to translate the physical results obtained at damage (index) cities into benefits expressed in dollars. The criteria used in this method of approach are given in Table H-21.

d. The physical effects on the Basin due to any modification of the flood flow characteristic was evaluated only with reference to certain index cities. Stage-discharge, stage-damage, and discharge-frequency relationships were prepared for these index points.

e. Initially, potential damage at the index points is evaluated for existing (preproject) conditions. The same locations are evaluated again, using the modified conditions of the proposed project. The potential benefit is the decrease in damage between preproject and postproject conditions. Normally, a proposed project will cause only one of the three basic relationships to change--either the discharge-frequency relationship, the stage-discharge relationship, or the stage-damage relationship. A flood control reservoirs's ability to hold back or to reduce the peak flows at a downstream point results in a modification of the discharge-frequency relationship. In the screening study the discharge-frequency relationship was considered the only variable resulting from the proposed reservoirs.

35. RESERVOIR SITES CONSIDERED. In the early stages of this comprehensive study, the Corps of Engineers tabulated data on 79 reservoir sites for use by the participating agencies. The sites were inventoried without regard to use or final purpose. The 79 sites included all sites identified in prior investigations by the Corps of Engineers and the Michigan Water Resources Commission and those identified in other available published data. This original listing of sites was supplemented by other possible sites found by inspection of topographic maps. Inspection of the 79 sites (Plate H-22) showed many overlapping impoundments, since there was no attempt to pass judgment on the comparative worth of adjacent sites during the inventory stage of the study. Sites were included if they appeared reasonable and were capable of development as a reservoir site.

36. HYDRAULIC COMPUTATIONS. The hydraulic considerations, tests, and results are summarized below. Essentially they consist of routing three different size floods to the reservoirs, impounding the flow, and then routing controlled releases downstream past the urban damage centers using holdout routing techniques. The controlled release schedule was optimized to provide near maximum flood control storage space utilization. The results of the holdout routings were then used to develop modified discharge-frequency relationships at the affected index cities. This basic procedure was repeated for various reservoir groupings and for various storage sizes in each grouping.

a. The results of these hydraulic studies are best illustrated by the modified discharge-frequency relationship at the five index cities for the reservoir schemes tested. Table H-22 is a tabulation of the relationships developed. This table illustrates the scope of the hydraulic investigation; representative examples of the results are shown in Figures H-11 thru H-20.

TABLE H-22

SUMMARY OF MODIFIED DISCHARGE FREQUENCY RELATIONSHIPS

RESERVOIR SITE(S) TESTED		INDEX POINTS				
Site No(s)	Site Name(s)	East Lansing *	Lansing *	Ionia *	Lowell *	Grand Rapids *
57	Okemos	1	1	MR	MR	MR
58	Williamston	2	2	MR	MR	MR
57 & 58	Okemos & Williamston	1	1	MR	MR	MR
5	Millett	NA	1	MR	MR	MR
6	Dimondale	NA	1	MR	MR	MR
7	Onondaga	NA	2	MR	MR	MR
8	Rives Junction	NA	2	MR	MR	MR
62	Tompkins Center	NA	2	MR	MR	MR
63	Portage	NA	2	MR	MR	MR
73	Smithville	NA	1	MR	MR	MR
5 & 6	Millett & Dimondale	NA	2	MR	MR	MR
5 & 7	Millett & Onondaga	NA	2	MR	MR	MR
5 & 57	Millett & Okemos	1	1	MR	MR	MR
5 & 58	Millett & Williamston	1	1	MR	MR	MR
5 & 62	Millett & Tompkins Center	NA	1	MR	MR	MR
5 & 73	Millett & Smithville	NA	1	MR	MR	MR
6 & 57	Dimondale & Okemos	1	1	MR	MR	MR
6 & 58	Dimondale & Williamston	1	1	MR	MR	MR
6 & 62	Dimondale & Tompkins Center	NA	1	MR	MR	MR
6 & 73	Dimondale & Smithville	NA	1	MR	MR	MR
7 & 57	Onondaga & Okemos	1	1	MR	MR	MR
7 & 58	Onondaga & Williamston	1	1	MR	MR	MR
7 & 62	Onondaga & Tompkins Center	NA	1	MR	MR	MR
8 & 62	Rives Junction & Tompkins Center	NA	1	MR	MR	MR
57 & 62	Okemos & Tompkins Center	1	1	MR	MR	MR
57 & 73	Okemos & Smithville	1	1	MR	MR	MR
58 & 62	Williamston & Tompkins Center	1	1	MR	MR	MR
58 & 73	Williamston & Smithville	1	1	MR	MR	MR
62 & 73	Tompkins Center & Smithville	1	1	MR	MR	MR
5,7 & 58	Millett, Onondaga, & Williamston	1	1	MR	MR	MR
5,57,62	Millett, Okemos, & Tompkins Center	1	1	MR	MR	MR
5,58,62	Millett, Williamston & Tompkins Center	1	1	MR	MR	MR
6,57,62	Dimondale, Okemos & Tompkins Ctr.	1	1	MR	MR	MR
6,57,73	Dimondale, Okemos & Smithville	1	1	MR	MR	MR
6,58,62	Dimondale, Williamston & Tompkins Center	1	1	MR	MR	MR

MR Minimal Reduction
NA Not Applicable (Physically not possible)

* Number of reservoir schemes (sizes) tested or can be interpreted from test results.

TABLE H-22(Cont'd)

Site No(s)	Site Name(s)	East Lansing *	Lansing *	Ionia *	Lowell *	Grand Rapids *
6,62,73	Dimondale, Tompkins Center & Smithville	NA	1	MR	MR	MR
57,62,73	Okemos, Tompkins Center & Smithville	1	1	MR	MR	MR
58,62,73	Williamston, Tompkins Center & Smithville	1	1	MR	MR	MR
1	Lyons	NA	NA	3	3	3
2 or 3	Portland	NA	NA	3	3	3
4	Danby	NA	NA	3	3	3
42	Prairie Creek	NA	NA	2	2	2
45	Stoney Creek	NA	NA	3	3	3
46	Muir	NA	NA	3	3	3
47	Fish Creek	NA	NA	3	3	3
47a	Fish Creek	NA	NA	3	3	3
48	Pine Creek	NA	NA	2	2	2
49	Elsie	NA	NA	3	3	3
51 or 52	Portland (Lookingglass)	NA	NA	3	3	3
53	Wacousta	NA	NA	2	2	2
54	Lainsburg	NA	NA	2	2	2
2 & 46	Portland & Muir	NA	NA	1	1	1
38	Lower Flat	NA	NA	NA	3	3
50	Dickerson	NA	NA	NA	3	3
76	Amsden	NA	NA	NA	3	3
19	Rockford	NA	NA	NA	NA	2
20	Childsdale	NA	NA	NA	NA	1
22	Lebarge	NA	NA	NA	NA	3
23	Lower Coldwater	NA	NA	NA	NA	2
26	Freeport	NA	NA	NA	NA	2
28	Irving	NA	NA	NA	NA	1
36 or 36b	Vermontville	NA	NA	NA	NA	3
36a	Vermontville	NA	NA	NA	NA	3
65	Alaska	NA	NA	NA	NA	1
2 & 22	Portland & Lebarge	NA	NA	NA	NA	1
22 & 46	Lebarge & Muir	NA	NA	NA	NA	1
2,22 & 46	Portland, Lebarge & Muir	NA	NA	NA	NA	1

MR Minimal Reduction
NA Not Applicable (Physically not possible)

* Number of reservoir schemes (sizes) tested or can be interpreted from test results.

37. DAMAGE COMPUTATIONS. The approach for computing average annual damages at each of the index cities was the same for all types of flood control modifications proposed. The average annual damages were computed by integrating the ordinates of the curve defining the damage-frequency relationship. The damage-frequency relationship is developed by combining the discharge-frequency, stage-discharge and stage-damage relationships.

a. The integration computation is usually accomplished by measuring the area under the curve with a planimeter. The preventable damage resulting from any improvement in the difference between the average annual damage value with and without the considered improvement.

b. A computer program was developed to make the average annual damage calculation. The program uses the same technique as the manual approach except that an analytical instead of a graphic integration of damage-frequency ordinates is used. Comparable results are obtained by computer and manual methods.

c. Preliminary damage estimates were made prior to damage studies for each city where detailed flood control studies were made. Preliminary studies provide damage information as to the magnitude and severity of flood problems. The intent of these preliminary damage estimates was to compare the alternative plans of flood control protection and the order of magnitude of the potential benefits. Hence, damage values given in the various reservoir plans of protection should not be compared with updated damage estimates made for those locations where detailed flood control studies were performed.

38. RESERVOIR SITES STUDIED. Review of hydrologic studies and damage patterns illustrated that for initial reservoir screening studies the Basin could be divided into Upper and Lower sub-basins, separated by a line just downstream of Lansing. Subsequent studies illustrated that there was little need to test for effect outside the pertinent sub-basin; however, the more promising schemes were tested for their effect in both sub-basins.

a. Reservoirs upstream of Lansing. Seventeen of the 79 potential reservoir sites are located in the Upper Basin (See plate H-22). The following eight sites were further analyzed:

(1) Site No. 7, Onondaga

(2) Site No. 8, Rives Junction

(3) Site No. 62, Tompkins Center

(4) Site No. 63, Portage

(5) Site No. 5, Millett

(6) Site No. 73, Smithville

(7) Site No. 57, Okemos

(8) Site No. 58, Williamston

(1) The effects of floods approximately equal to the 1947 flood, one-half this flood, and twice the 1947 flood were routed through the reservoir units under consideration. Various sizes of reservoir as well as combinations of reservoirs were tested in this manner. The test results were translated into potential damage reduction for the East Lansing and Lansing damage centers. The combined damage reduction of Lansing and East Lansing were compared to the reservoir cost estimated in the initial site inventory. Table H-23 shows the residual damages, the potential benefits on an average annual basis, an estimate of first cost, of annual cost, and of annual operation and maintenance cost and the resulting benefit-cost ratio, for each scheme that was evaluated.

(2) Analysis of the tabulated results shows that only reservoir sites on the Red Cedar River have any potential for single-purpose flood control reservoirs. The biggest increment of potential damage starts at East Lansing and continues along the Red Cedar river; therefore, Grand River reservoirs can contribute little, if anything toward protecting this reach. No Grand River reservoir site could derive enough potential benefits to offset the estimated construction cost to develop the site.

b. Reservoir sites downstream of Lansing. Sixty-two of the 79 reservoir sites considered are located downstream of Lansing. Eight of the 62 sites are located downstream of Grand Rapids and are considered not to have a flood prevention potential. Between Lansing and Grand Rapids 54 sites remained; of which 26 were judged unsuitable either because they control too small a drainage area or because their storage capacity is too small to control their drainage area effectively. Twenty-eight sites required further consideration in determining their effectiveness (WRC denotes selection by the Water Resources Commission):

(1) Site No. 1, Lyons on Grand River

(2) Site No. 2, Portland on Grand River

(3) Site No. 3, Portland on Grand River (WRC)

(4) Site No. 4, Danby on Grand River

(5) Site No. 51, Portland on Lookingglass River (WRC)

(6) Site No. 52, Portland on Lookingglass River

(7) Site No. 53, Wacousta on Lookingglass River

(8) Site No. 54, Laingsburg on Lookingglass River

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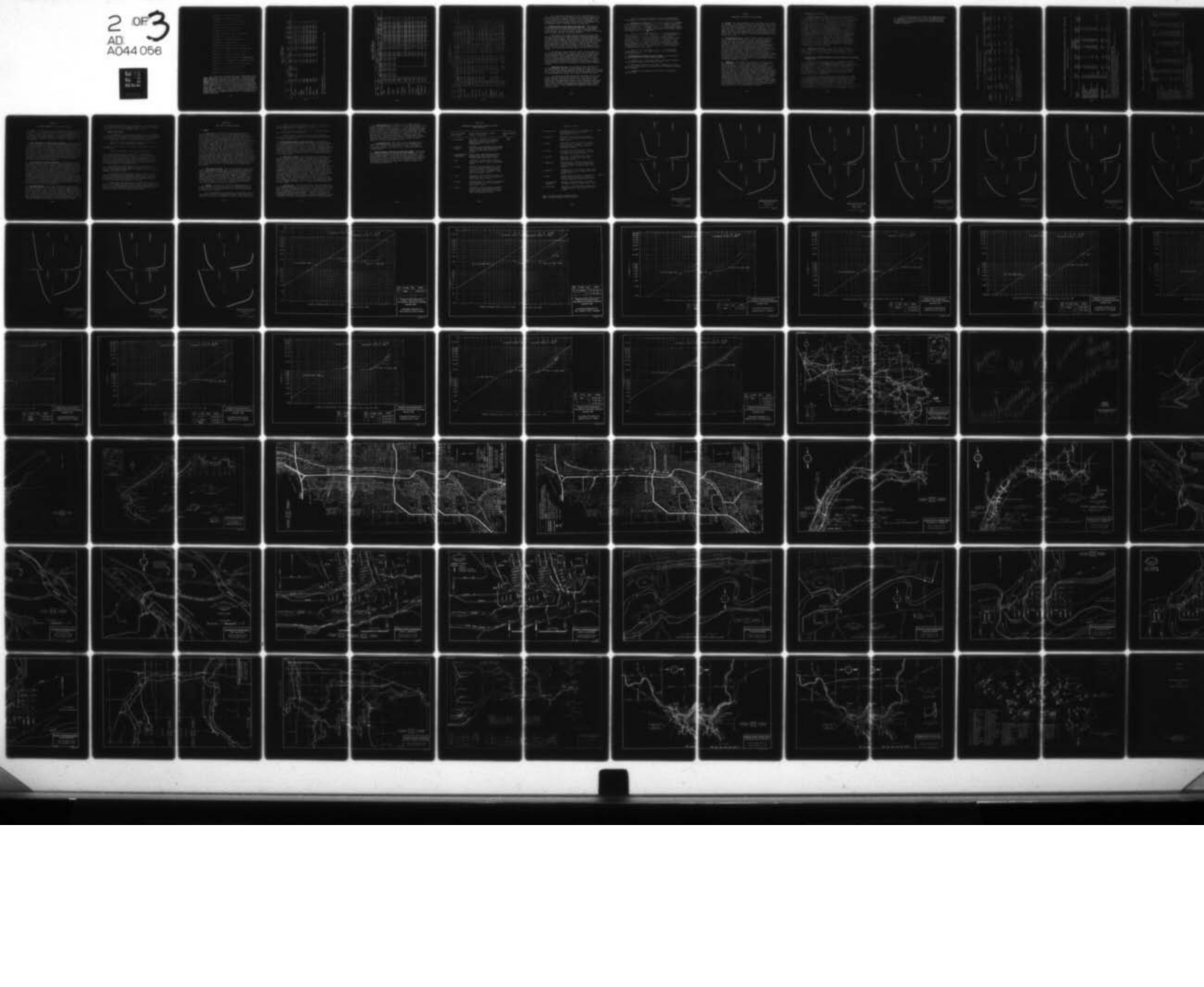

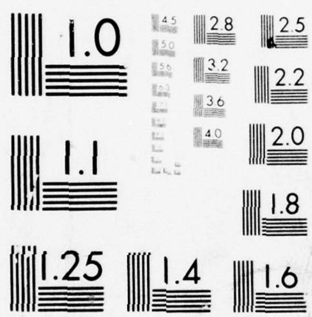

MICROCOPY RESOLUTION TEST CHART
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(9) Site No. 45, Stony Creek on Maple River

(10) Site No. 46, Muir on Maple River

(11) Site No. 47, Fish Creek on Maple River

(12) Site No. 47A, Fish Creek on Maple River

(13) Site No. 48, Pine on Maple River

(14) Site No. 49, Elsie on Maple River

(15) Site No. 42, Prairie Creek on Prairie Cre

(16) Site No. 38, Flat on Flat River

(17) Site No. 50, Dickerson on Flat River

(18) Site No. 76, Amsden on Flat River

(19) Site No. 22, Labarge on Thornapple River

(20) Site No. 23, Lower Coldwater on Thornappl

(21) Site No. 26, Freeport on Thornapple River

(22) Site No. 28, Irving on Thornapple River

(23) Site No. 36, Vermontville (WRC) on Thorna

(24) Site No. 36A, Vermontville (CE) on Thorna

(25) Site No. 36B, Vermontville on Thornapple

(26) Site No. 65, Alaska on Thornapple River

(27) Site No. 19, Rockford on Rogue River

(28) Site No. 20, Childsdale on Rogue River

(1) Ionia, Lowell and Grand Rapids were selected damage cities for the lower Grand River sub-basin. These suffer approximately 74 percent of the estimated total ave damages in the lower Grand River sub-basin. The sites wer hydraulic effectiveness by routing the 1948 flood and twic flood through the reservoirs and calculating effects at th cities. Modified discharge-frequency relationships were d the routings. In a few cases, closely related reservoirs common curve; for example, the two alternate reservoir sit on the Grand River. A computer program was then used to e benefit potential in the manner described earlier. The re sented in Table H-24.

TABLE H-23
SUMMARY OF ANALYTICAL SCREENING OF
RESERVOIRS UPSTREAM OF LANSING

RESERVOIR SITES			REDUCTION BENEFITS* (Dollars)					PRELIMINARY COST (Dollars)					REMARKS
			EAST LANSING		LANSING								
NO.	NAME	SIZE AC.FT.	Residual Damage	Potential Benefits	Residual Damage	Potential Benefits	TOTAL (5)+(7)	FIRST COST	AVERAGE ANNUAL COST	ANNUAL O&M COST	ANNUAL TOTAL (10)+(11)	BENEFIT COST RATIO	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	
57	OKEMOS	23,800	21,468	213,272	13,316	41,277	254,549	4,394,000	175,000	29,000	204,000	1.25	
58	WILLIAMSTON	17,000	22,614	212,126	17,249	37,344	249,470	10,221,000	407,000	46,000	453,000	0.55	
		67,000	22,614	212,126	17,249	37,344	249,470	10,221,000	407,000	46,000	453,000	0.55	
5	MILLET	63,700			7,495	47,098	47,098	8,955,000	356,000	43,000	399,000	0.12	
6	DIAMONDALE	14,500			18,869	35,723	35,723	3,484,000	153,000	25,000	178,000	0.20	
7	ONONDAGA	30,600			12,448	42,144	42,144	6,750,000	269,000	37,000	306,000	0.14	
		221,000			12,448	42,144	42,144	25,084,000	998,000	62,000	1,060,000	0.04	
8	RIVES JUNCTION	10,000			27,392	27,200	27,200	5,800,000	231,000	35,000	266,000	0.10	
		109,000			27,392	27,200	27,200	13,900,000	553,000	51,000	604,000	0.05	
62	TOMKINS CENTER	7,000			34,348	20,245	20,245	2,000,000	80,000	15,000	95,000	0.21	
		115,000			34,348	20,245	20,245	6,858,000	273,000	38,000	311,000	0.07	
63	PORTAGE	3,372			40,730	13,863	13,863	6,695,000	266,000	37,000	303,000	0.05	
		20,880			40,730	13,863	13,863	6,695,000	266,000	37,000	303,000	0.05	
73	SMITHVILLE	44,000			8,736	45,856	45,856	7,357,000	293,000	39,000	332,000	0.14	

* Based on preliminary damage data.

NOTE: The six significant figures shown for average annual damages are a characteristic of the computer program.

TABLE H-24
SUMMARY OF ANALYTICAL SCREENING OF
RESERVOIRS DOWNSTREAM OF LANSING

RESERVOIR SITES			REDUCTION BENEFITS (Dollars)							PRELIMINARY COST (Dollars)				REMARKS
NO.	NAME	SIZE AC.FT.	IONIA Residual Damage	IONIA Potential Benefits	LOWELL Residual Damage	LOWELL Potential Benefits	GRAND RAPIDS Residual Damage	GRAND RAPIDS Potential Benefits	TOTAL (5)+(7)+(9)	FIRST COST	AVERAGE ANNUAL COST	ANNUAL O&M COST	ANNUAL TOTAL (12)+(13)	BENEFITS COST RATIO
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
1	LYONS	30,000	35,662	11,970	41,445	14,445	303,525	84,701	111,116	6,250,000	249,000	36,000	285,000	0.39
		40,000	33,333	14,299	37,102	18,697	261,503	126,723	159,719	7,200,000	287,000	38,000	325,000	0.49
		56,000	31,694	15,938	34,639	21,159	234,190	154,037	191,134	8,800,000	350,000	42,000	392,000	0.49
2&3	PORTLAND	30,000	35,424	12,208	41,313	14,486	336,791	51,436	78,130	4,800,000	191,000	32,000	223,000	0.35
		50,000	33,540	14,092	38,885	16,913	276,825	111,401	142,406	4,900,000	195,000	32,000	227,000	0.62
		158,000	33,235	14,397	37,874	17,924	247,861	140,366	172,687	11,600,000	462,000	48,000	510,000	0.34
4	DANBY	20,000	37,059	10,573	44,521	11,277	367,736	20,490	42,340	3,330,000	133,000	24,000	157,000	0.27
		30,000	35,479	12,153	41,383	14,416	319,927	68,299	94,868	4,030,000	160,000	28,000	188,000	0.50
		37,500	34,488	13,144	39,877	15,922	295,494	92,733	121,799	4,400,000	175,000	29,000	204,000	0.60
19	ROCKFORD	9,359					348,976	39,250	39,250	1,910,000	76,000	14,000	90,000	0.44
		10,800					348,976	39,250	39,250	2,050,000	82,000	15,000	97,000	0.41
		78,500					348,976	39,250	39,250	6,200,000	247,000	36,000	283,000	0.14
20	CHILDSDALE	4,500					373,887	14,339	14,339	1,710,000	68,000	13,000	81,000	0.18
22	LABARGE	46,589					213,343	174,884	174,884	4,450,000	177,000	30,000	207,000	0.84
		81,763					179,392	208,834	208,834	6,750,000	267,000	37,000	304,000	0.69
		115,000					179,392	208,834	208,834	8,700,000	346,000	42,000	388,000	0.54
23	LOWER COLDWATER	14,445					326,873	61,354	61,354	1,850,000	74,000	13,000	87,000	0.70
		68,400					326,873	61,354	61,354	4,500,000	179,000	30,000	209,000	0.29
24	FREEPORT	4,984					382,267	5,960	5,960	1,020,000	41,000	10,000	51,000	0.12
		24,200					382,267	5,960	5,960	2,600,000	103,000	20,000	123,000	0.05
28	IRVING	5,700					382,416	5,810	5,810	2,680,000	107,000	20,000	127,000	0.05
36&	VERMONTVILLE	17,861					309,193	79,033	79,033	5,550,000	221,000	33,000	254,000	0.31
36B		87,600					309,193	79,033	79,033	8,800,000	350,000	43,000	393,000	0.20
36A	VERMONTVILLE	14,517					325,622	62,605	62,605	2,050,000	82,000	15,000	97,000	0.65
		20,900					325,622	62,605	62,605	3,250,000	129,000	24,000	153,000	0.41
38	LOWER FLAT	43,979			37,726	18,072	353,399	34,827	52,899	4,200,000	167,000	28,000	195,000	0.27
		51,600			37,726	18,072	353,399	34,827	52,899	4,880,000	194,000	32,000	226,000	0.23

TABLE H-[illegible]

SUMMARY OF ANALYTICAL SCREENING OF RESERVOIRS DOWNSTREAM OF LANSING

RESERVOIR SITES			REDUCTION BENEFITS (Dollars)							PRELIMINARY COST (Dollars)					REMARKS
NO.	NAME	SIZE AC.FT.	IONIA Residual Damage	IONIA Potential Benefits	LOWELL Residual Damage	LOWELL Potential Benefits	GRAND RAPIDS Residual Damage	GRAND RAPIDS Potential Benefits	TOTAL (5)+(7)(9)	FIRST COST	AVERAGE ANNUAL COST	ANNUAL O&M COST	ANNUAL TOTAL (12)+(13)	BENEFITS COST RATIO	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	
42	PRAIRIE CREEK	9,937	45,003	2,629	48,792	7,007	353,399	34,827	44,463	1,500,000	60,000	10,000	70,000	0.63	
		61,900	45,003	2,629	48,792	7,007	353,399	34,827	44,463	6,800,000	270,000	38,000	308,000	0.14	
45	STONEY CREEK	22,870	41,242	6,390	44,267	11,531	352,947	35,279	53,200	2,780,000	110,000	21,000	131,000	0.41	
		48,950	41,242	6,390	44,267	11,531	352,947	35,279	53,200	4,650,000	185,000	31,000	216,000	0.25	
46	MUIR	50,000	31,460	16,172	37,454	18,345	317,562	70,665	105,182	11,100,000	442,000	47,000	489,000	0.21	
		70,000	29,570	18,062	33,714	22,085	272,045	116,182	156,329	11,100,000	442,000	47,000	489,000	0.32	
		89,800	27,680	19,952	31,365	24,434	244,083	144,143	188,529	11,100,000	442,000	47,000	489,000	0.39	
47	FISH CREEK	31,394	39,833	7,799	42,659	13,140	276,524	111,702	132,641	5,450,000	217,000	33,000	250,000	0.53	
		35,600	39,833	7,799	42,659	13,140	276,524	111,702	132,641	6,100,000	243,000	36,000	279,000	0.48	
47A	FISH CREEK	26,472	40,974	6,658	44,759	11,039	314,476	73,750	91,447	1,700,000	68,000	13,000	81,000	1.12	TOO SMALL
		97,000	40,974	6,658	44,759	11,039	314,476	73,750	91,447	5,100,000	203,000	32,000	235,000	0.39	
48	PINE CREEK	6,950	43,812	3,820	44,502	11,297	388,227	0	15,117	1,100,000	44,000	10,000	54,000	0.28	
		47,490	43,812	3,820	44,502	11,297	388,227	0	15,117	5,000,000	199,000	32,000	231,000	0.07	
49	ELSIE	20,052	40,906	6,726	44,563	11,235	324,604	63,623	81,584	2,450,000	97,000	18,000	115,000	0.71	
		61,000	40,906	6,726	44,563	11,235	324,604	63,623	81,584	7,450,000	296,000	39,000	335,000	0.29	
50	DICKERSON	3,661			49,117	6,681	378,753	9,474	16,155	1,040,000	41,000	10,000	51,000	0.32	
		5,963			49,117	6,681	378,753	9,474	16,155	1,040,000	41,000	10,000	51,000	0.32	
		14,900			49,117	6,681	378,753	9,474	16,155	1,620,000	64,000	11,000	75,000	0.22	
51&	LOOKINGGLASS	18,729	41,721	5,911	46,904	8,895	346,820	41,407	56,213	2,320,000	92,000	17,000	109,000	0.51	
52	PORTLAND	35,970	41,721	5,911	46,904	8,895	346,820	41,407	56,213	3,870,000	154,000	27,000	181,000	0.31	
53	WACOUSTA	10,910	43,399	4,233	50,404	5,395	368,617	19,609	29,237	2,280,000	91,000	17,000	108,000	0.27	
54	LAINSBURG	9,254	43,903	3,729	50,493	5,305	385,717	2,510	11,544	830,000	33,000	10,000	43,000	0.27	
		11,500	43,903	3,729	50,493	5,305	385,717	2,510	11,544	830,000	33,000	10,000	43,000	0.27	
65	ALASKA	40,620					227,760	160,466	160,466	5,400,000	215,000	35,000	250,000	0.64	
76	AMSDEN	3,461			51,162	4,637	380,469	7,758	12,395	2,300,000	92,000	17,000	109,000	0.11	
		5,659			51,162	4,637	380,469	7,758	12,395	2,300,000	92,000	17,000	109,000	0.11	
		19,000			51,162	4,637	380,469	7,758	12,395	2,300,000	92,000	17,000	109,000	0.11	

(2) Inspection of the tabulated results shows that there is no single-purpose flood control reservoir having any economic consequence in the lower Grand River sub-basin. Several of the sites show good potential for flood control pools in a multi-purpose reservoir development. The single-purpose reservoir studies in the lower basin were terminated after development and review of the data tabulated in Table H-24.

39. SECONDARY ANALYSIS OF RED CEDAR RIVER RESERVOIRS. The preliminary studies indicated that damage along the Red Cedar River of East Lansing is high and either one of the two reservoir sites on the river might protect the area. The type and extent of damages were studied to understand better the degree and kind of protection required.

a. The vulnerable area extends from the junction of the Red Cedar River and Grand River for 6.5 miles upstream to the Michigan State University campus in East Lansing. The flood plain is encroached upon within the entire reach, although the flood problem has not been totally disregarded by the local people. The lower portions of the flood plain have been left vacant or occupied by floodproof structures. The area will not suffer great damage until a flood flow in excess of 4,000 cfs occurs. For comparison, the 1947 flood had a flow of 5920 cfs. To be economically justified, any plan must include protection against the high but less frequent floods.

b. The same basic design floods were analyzed in this design as in the earlier preliminary studies. However, a more precise reservoir regulation system was utilized. A computer program titled "Spillway rating and flood routing", which optimizes the use of the flood control pool, was used. This program has several considerations built into it which it must check before computing the release for each period. It considers downstream channel capacities and unused flood control storage, projects future short-term inflows, and incorporates all current Corps of Engineers criteria.

c. Okemos reservoir site. The preliminary studies indicated that the Okemos reservoir site had a favorable benefit-cost ratio. As the most promising site, detailed hydraulic and hydrologic studies were conducted for it. These studies revealed that the site was not capable of successfully performing hydraulically through a full range of possible flood flows.

(1) The site is ideally located for flood control, but its topographic limitations handicap its effectiveness. The site has a limited storage capacity of only 23,800 acre feet. While this volume is very effective in controlling smaller floods, it is not adequate to control the larger floods. Secondly, the dam structure itself would have a negligible effect on flows if the spillway design flood (maximum probable flood) of 26,000 cfs occurred. Hence, minimum Corps of Engineers design criteria could not be met.

(2) The Okemos site was dropped from further consideration as a single-purpose flood control reservoir due to its physical shortcomings.

d. Williamston reservoir site. The Williamston reservoir was analyzed in detail for the new conditions. Three sizes of impoundment were investigated: the 45,000 acre-feet maximum pool and lesser pools of 35,000 acre-feet and 27,500 acre-feet of storage. Three different dam-spillway configurations were also studied. All spillway configurations were designed to pass the maximum probable flood of 26,000 cfs.

(1) Current topographic data indicate that the 35,000 acre-feet flood control pool reservoir at elevation 881 feet yields the maximum flood reduction potential for the site. Development at this elevation requires 11,000 acres estimated at $4,200,000, $2,000,000 of major highway relocation, and $500,000 of railroad modification. The total cost for the structure, lands, and necessary relocations is $10,000,000. If the cost is amortized over 50 years at 4-5/8 percent interest and an annual operation and maintenance charge of $47,000, then the annual cost for the reservoir would be $563,000. The dollar value for the flood reduction is estimated at $261,209 per annum.

(2) The benefit-cost ratio for this plan is 0.46; therefore the Williamston reservoir site cannot be justified as a single-purpose flood control reservoir.

40. CONCLUSIONS ON FLOOD CONTROL RESERVOIR STUDIES. The flood control reservoir studies point out three significant factors:

a. Reservoirs built to meet single-purpose flood control needs are not economically feasible in the Grand River basin.

b. The physical capability of controlling floods by use of reservoirs has been demonstrated to be hydrologically and hydraulically feasible within the Basin.

c. Significant flood damage benefits do exist at several select reservoir sites.

SECTION V

FLOOD DAMAGE IN UPSTREAM WATERSHED AREAS

41. <u>GENERAL</u>. This section summarizes upstream watershed flood control studies made by the Department of Agriculture's Soil Conservation Service. For ease of evaluation and study the Basin was divided into eleven hydrologic sub-basins (See Appendix "M" - Agriculture, Plate 1). These sub-basins were further divided into study units. Reconnaissance and investigations were made of these study areas to determine the extent of flood damage. Where significant damages occurred in a specific upstream watershed, further studies were made. All watersheds investigated were under 250,000 acres in size.

42. <u>AVAILABLE DATA UTILIZED</u>. Reports, records, and data from Federal, State, local, and private agencies were used, including stream gage records, soils data, aerial photos, land use data, water supply and storage data, general geological information, and economic base information. Survey profiles and cross sections from Survey Reports on Major and Local Drainage for the Portage River, the Maple River, and Stony Creek, published by the Soil Conservation Service from 1958 to 1963, were extensively used. An Interim Survey Report on Major Drainage and Flood Control, published in 1959 by the U. S. Army Corps of Engineers, was also utilized. Field investigations of all projects were made by the Basin Planning Party, Soil Conservation Service. United States Geological Survey stream gage data were used to develop a drainage area-discharge relationship for each study area. The drainage area-discharge relationships were then related to estimated channel capacities to determine frequency of flooding.

43. <u>METHODOLOGY</u>. Flood damages were computed for the main stem and major tributaries of the various reaches studied. These damages were based upon estimates of average annual cropland acres flooded and the application of damage values developed from similar watersheds under the PL-566 program. Adjustments and updating of these damage values were made to reflect projected crop yields and adjusted normalized prices, as outlined in "Interim Price Standards for Planning and Evaluating Water and Related Land Resources", approved by the Interdepartmental Staff Committee, Water Resources Council, dated April 20, 1965. Channel lengths were determined from aerial photos. Extent of required channel excavation was determined by field examination of existing channels and by hydraulic calculation using grades from topographic maps. Installation costs were based on existing watershed projects. Cost estimates for operations and maintenance were based on experience gained in PL-566 work. Estimates of "other" and "non-agricultural" damages were made. If warranted, further detailed evaluations were made.

44. UPSTREAM AREA FLOOD DAMAGES

a. Present conditions. Studies indicate that floodwater damages of major significance occur in only three upstream area watersheds. They are the Portage River, the Maple River, and Stony Creek. The average annual floodwater damages in these three upland areas, under "without project" conditions, are estimated to be $389,819 (See Table H-25). Floodwater damages to crop and pasture amount to $359,339 or 92 percent of the total. This damage occurs on 16,500 acres of flood plain land. Floods have been experienced in all of the months of the growing season. Floods frequently occur at the time of spring breakup and force a delay in tillage operations, resulting in the delayed planting of crops normal to the general area. Planting of crops is often delayed several weeks, and when flooding occurs after planting it is necessary to repeat the entire operation which results in uneven stands, increased cost of production, and reduced yields. Thus, floodwater damages reduce, or sometimes entirely eliminate, the farm income from the bottomlands which tends to depress the local agricultural economy. Damages to other agricultural property, such as farm roads, fences, stored grains, and farm buildings, amount to $13,885 annually. Damages to non-agricultural facilities, such as public roads, road ditches, bridges, culverts, and transportation facilities, amount to $16,595 annually.

b. Project conditions 1980. Future average annual floodwater damages "with projects" have been calculated to be $50,082. It is contemplated that these projects will be in operation within the next 10 to 15 years and will provide a reduction in present floodwater damages of 87 percent.

45. SUMMARY OF OTHER UPSTREAM WATERSHED AREAS WITH POTENTIAL FOR DEVELOPMENT IN 10-15 YEARS.

a. There are 14 watershed areas that have a potential for development, including the three watersheds previously discussed. In these watersheds there is a two-fold problem of floodwater damages and associated inadequate drainage. Due to the flat topography of the flood plain, conventional stage-discharge evaluation procedures to determine floodwater damages were not applicable. Therefore, a "net income" method of evaluation was used. This method separates efficiency-type benefits, such as reduced costs of production and improved crop quality, from benefits due to increased production.

b. Joint flood prevention and drainage benefits accrue on cropland as a result of project measures which alleviate problems caused by floodwater and impaired drainage. Such benefits are: (1) reduced cost due to increased efficiency of productive inputs and reduced tillage operation; (2) improved quality benefits due to higher prices which reflect reduced dockage for crops that are undamaged by excess water; and (3) increased production benefits due to increases in crop yields. Each of these joint benefits has been credited equally to flood prevention and drainage.

c. Table H-26 and H-27 provide physical and economic data, and the location of the watersheds in the basin can be found in Appendix M - "Agriculture", Plate 3. For more detailed information see the Watershed Investigation Report for each of the specific watersheds, attached to Appendix M.

TABLE H-25 - AVERAGE ANNUAL FLOODWATER DAMAGES FOR SELECTED UPSTREAM AREAS

Grand River Basin, Michigan

		Present Floodwater Damages 1/				Future Floodwater Damages With Developments 2/			
Watershed Name 3/	Evaluation Unit	Crop and Pasture	Other Agricultural	Non-Agricultural	Total Floodwater Damages	Crop and Pasture	Other Agricultural	Non-Agricultural	Total Floodwater Damages
					(Dollars)				
Portage River	P-1,2, 3,4	150,167	7,885	11,295	169,347	22,526	1,185	1,695	25,406
Upper Maple	M-1,2,3, 4,5,8,9, 10,11	198,000 4/	6,000	5,300	209,300	20,500	300	2,200	23,000
Stony Creek	S-1,2,3, 4,5,6	11,172	--	--	11,172	1,676	--	--	1,676
TOTAL		359,339	13,885	16,595	389,819	44,702	1,485	3,895	50,082

1/ Price base - adjusted normalized prices.
2/ Estimated that developments will be in operation within 10-15 years.
3/ Physical and economic data are in Tables H-27 and H-28.
4/ Includes $12,500 indirect damages.

TABLE H-26 - SUMMARY OF UPSTREAM AREAS WITH POTENTIAL FOR DEVELOPMENT (10-15 YEARS) - PHYSICAL DATA

Grand River Basin, Michigan

Watershed Name	Evaluation Unit	Watershed Area (sq.mi.)	Flood 1/ Plain Area (Acres)	Flooding and Inadequate Drainage Area: Mineral Soil (Acres)	Flooding and Inadequate Drainage Area: Organic Soil (Acres)	Channel Improvement (Miles)	Structure Site (Number)
Twin Lakes Drain	UG-5	5.4	--	265	797	5.3	
Freeman Marsh Drain	UG-5	8.0	--	--	1,223	7.2	
Huntoon Lake	UG-5	11.6	--	511	696	6.4	
Perry Creek	UG-5	10.4	--	1,536	1,715	5.3	
Bly Lake	UG-8	11.7	--	1,302	1,367	8.8	
Eaton Rapids	UG-8	13.6	--	1,321	492	8.3	
Upper Columbia Creek	UG-9	18.3	--	1,527	1,019	7.6	
Portage River	P-1,2,3,4	185.8	7,100	3,420	4,940	21.5	
Prairie Creek	MG-6	46.0	--	2,386	615	8.4	
Libhart Creek	MG-7	17.1	--	1,039	637	8.4	
Upper Maple River 2/	M-1,2,3,4, 5,8,9,10, 11	312.0	16,500	24,470	4,390	40.0 3/	109-110 4/
Hayworth Creek	M-12	93.5	--	2,432	1,950	14.0	
Stony Creek	S-1,2,3,4, 5,6	178.1	2,227	7,221	1,024	42.1	
Rogue River	R-1,2,3	37.9	3,100	--	3,100	10.6	
TOTAL		949.4	28,927	47,430	23,965	193.9	

1/ This area is also included in flooding and inadequate drainage area.
2/ Data from PL-566 draft of Work Plan, both East and West, March 1968.
3/ In addition to channel improvement, there are two multiple-purpose structures, 29 miles of dike construction, and four drainage pumping stations.
4/ Multiple-purpose structures - flood prevention and recreation.

TABLE H-27 - SUMMARY OF UPSTREAM AREAS WITH POTENTIAL FOR DEVELOPMENT (10-15 YEARS) - ECONOMIC DATA

Grand River Basin, Michigan

(Dollars)

	Average Annual Benefits 1/							
	Flood Prevention							
Watershed Name	Flood Damage Reduction	More Intensive Land Use	Drainage	Recreation	Total	Total 2/ Installation Cost	Average 3/ Annual Installation Cost	Benefit Cost Ratio
Twin Lakes Drain	--	2,570	2,571	--	5,141	90,700	4,494	1.14:1
Freeman Marsh Drain	--	3,391	3,391	--	6,782	120,000	5,928	1.15:1
Huntoon Lake	--	4,292	4,293	--	8,585	110,600	5,425	1.58:1
Perry Creek	--	5,000	5,000	--	10,000	105,300	5,170	1.93:1
Bly Lake	--	5,889	5,889	--	11,778	148,700	7,307	1.61:1
Eaton Rapids	--	5,032	5,033	--	10,065	140,900	6,929	1.45:1
Upper Columbia Creek	--	5,869	5,870	--	11,739	119,300	6,119	1.92:1
Portage Creek	143,941	--	93,869	--	237,810	3,736,350	171,378	1.39:1
Prairie Creek	--	8,100	8,101	--	16,201	230,500	11,488	1.41:1
Libhart Creek	--	5,162	5,163	--	10,325	128,100	6,680	1.55:1
Upper Maple River 4/	186,300	92,700	106,900	831,600	1,425,200 5/	10,795,500	610,600	2.33:1
Hayworth Creek	--	25,575	25,575	--	51,150	531,700	25,384	2.00:1
Stony Creek	9,496	27,009	27,009	--	63,514	801,200	43,103	1.47:1
Rogue River	--	38,750	38,750	--	77,500	1,075,650	46,375	1.67:1
TOTAL	339,737	229,339	337,414	831,600	1,945,790	18,134,500	956,380	

1/ Price base - adjusted normalized prices.
2/ Price base - 1964, Upper Maple River Watershed - 1967.
3/ Amortized at 3¼ percent over a 50-year period, includes O&M cost.
4/ Data from draft Work Plan, both East and West - March 1968.
5/ Includes $207,700 for local secondary benefits.

SECTION VI

STREAMFLOW FORECASTING IN THE GRAND RIVER BASIN

46. GENERAL. Future plans of basin development should consider the role of the river and flood forecast service as a means of flood control through reduction in property damage and loss of life from floods made possible by advance warnings. Also, extension of the river forecast services to cover daily and long-range forecasts of streamflow for water supply, pollution abatement, recreation, and other water resources requirements should be considered.

47. FLOOD FORECASTING AS A MEANS OF FLOOD PROTECTION. Timely and accurate predictions of impending floods, when used in connection with an established flood plain management plan, provide substantial reductions in the loss of life and property. This method is especially effective in areas where the benefit-cost ratio does not justify a public investment in flood control structures. It is also effective where only partial protection is provided and it is necessary to make decisions as to emergency measures to be taken or evacuation ordered. In fact, there may be numerous cases where a relatively low-cost flood forecasting and warning service, when coupled with local plans for occasional evacuation and protection measures, will be more acceptable to the community than little-used flood control structures which are expensive to operate and maintain.

48. DAILY FORECASTS FOR RESERVOIR OPERATIONS. Most storage reservoirs are constructed to serve multiple-purpose objectives and require complex management to attain efficient operation. Without forecasting, there must be an inflexible assignment of reservoir capacity to specified uses such as flood control, conservation, power generation, and low-flow stabilization. With effective flow forecasting, the use of reservoir capacity can be made more flexible and thus become truly multiple-purpose. Streamflow is a function of precipitation and it follows that any outlook can be extended and improved by application of available weather forecasts. As an example, flood storage in a reservoir may be safely evacuated if there is a reasonable indication that these releases will not coincide with downstream runoff from excessive rains. Likewise, flood storage may be retained in reservoirs for use when needed if there can be assurance that warning will come far enough in advance to permit evacuation to a safe level before serious increases in inflow are experienced.

49. FLASH FLOOD WARNINGS. Flash floods resulting from high-intensity short-duration rainfall account for most of the loss of life and considerable loss to movable property. The warning time for communities subject to this type of flood is very short. It is feasible to establish reporting networks around these communities and train local representatives in the use of forecast procedures to be applied to the reports. Technical developments in radar and its application to the immediate detection of areas of heavy rainfall have been sensational. Radar operators can call local representatives immediately upon detection of areas of possible excessive

precipitation and alert them to possible flooding. These measures, when used in connection with a well-organized plan for evacuation, can substantially reduce loss of life and damage to movable property.

50. WEATHER BUREAU PROGRAM

a. The ESSA Weather Bureau provides a public river and flood forecast and warning service for the Grand River Basin through its offices at Lansing and Grand Rapids. The Lansing Office issues the forecasts for points at and above Grand Ledge, including the following river gaging points:

Grand River at Grand Ledge, Lansing, Dimondale, and Eaton Rapids
Red Cedar River at East Lansing and Williamston

The Grand Rapids Office issues the forecasts for the following points in the lower Basin:

Grand River at Portland, Ionia, Lowell, and Grand Rapids

For forecast purposes, these offices maintain a reporting network of twenty river and rainfall stations which report by telephone every six hours whenever established rainfall, snowmelt, or river stage criteria are met. The Bureau cooperates with the U. S. Geological Survey in the mutual use of river gaging facilities needed in the forecasting service. Daily gage heights for two river gaging stations, Lansing and Grand Rapids, are published annually by the Weather Bureau.

b. The Grand Basin is well within the effective operating range of modern Weather Surveillance Radar (WSR-57) at Chicago and Detroit. In addition, supplemental equipment (WSR-3) is operated at Flint and Muskegon, Michigan, and Ft. Wayne, Indiana.

c. The basic data collection program includes a network of about thirty-five hydrologic and climatological substations in the Grand River Basin recording precipitation, temperature, and other data. These data are available on punch cards and are published in Climatological Data and Hourly Precipitation Data bulletins for Michigan.

d. A State weather forecasting center is maintained at Detroit. In addition to daily State-wide public weather forecasts, other special forecast services, including quantitative precipitation forecasts, severe weather warning, and other climatological weather services for the Grand River Basin, are rendered by the local Weather Bureau Offices.

SECTION VII

FLOOD PLAIN INFORMATION STUDIES

51. GENERAL

a. Flood plains. A flood plain is the relatively flat area of lowlands adjoining a river, stream, or water course which has been or may be covered by flood water. Cross-sectional areas of the Grand River and its major tributaries are generally wide with only a few feet of water flowing in the flat-bottomed channels during normal flow. Most of the stream banks retain the average annual peak flow. From Grand Haven to Grand Rapids, the water rises from 12 to 18 feet above low water in flood stage. During floods the river valley below Grand Rapids is flooded to a width of 1000 to 4000 feet. Between Grand Rapids and Ionia the flood level for extreme floods is approximately 20 feet above low water. From Ionia to Lansing the flood level is as much as 15 feet above low water. Flood plains there vary from 500 to 2600 feet wide. From Lansing to Jackson the river rises as much as 10 feet in flood stage but the flooded area is not extensive. And above Jackson practically no troubles arise from floods, which are partially controlled by the operation of the Jackson and Michigan Center dams. The tributaries of the Grand River, excepting the Maple River, have relatively steep slopes, from 3 to 11 feet per mile. They do not cause serious flood damage except for the lower few miles which are flooded by backwater from the main stream. Flood stages are generally 5 to 10 feet above low water. The Maple River has an average fall of 1.6 feet per mile and flows through flat summit swamps between Lakes Huron and Michigan.

b. Flood plain regulation. The need for regulation of flood plain use has been recognized for some time. The first agency to compile data and to supply advice concerning flood plains was the Tennessee Valley Authority in 1952. The U. S. Geological Survey has since adopted this approach. Congress authorized the Corps of Engineers to provide a similar service by the Flood Control Act of 1960. A condition of this authorization is "That the necessary surveys and studies will be made and such information and advice will be provided for specific localities only upon the request of a State or a responsible local governmental agency and upon approval by the Chief of Engineers."

c. Purpose. The purpose of a flood plain information study is to provide technical guidance and advice to give a factual basis for use by State and local governments in planning and regulating flood plains. The objectives of a study are:

(1) The compilation and presentation of all pertinent information on past floods and on potential flood hazards. This includes identification of areas subject to inundation by floods of various frequencies.

(2) The encouragement of prudent use of river valleys in order to reduce future flood damages, to develop land use plans, and to preserve channels adequate to remove the flood flows.

(3) The publicizing of information for the guidance of anyone having an interest in the specific areas.

(4) The reduction of future local and Federal expenditures for flood control projects to protect developments which, in the absence of the study, would be built.

52. STUDIES ACTIVELY FUNDED IN GRAND RIVER BASIN. The Michigan Water Resources Commission has made application for certain flood plain information studies in the Grand River basin. Two of these studies deal with two particular reaches of the Grand River. Two more are studies of the Red Cedar and Lookingglass Rivers. The Tri-County Regional Planning Commission representing Clinton, Eaton and Ingham counties sponsored these actions. These four studies have been approved and funds have been provided to complete studies. They are designated study A, B, C, and D and are outlined in the following text.

a. Grand River - Lansing. This study area includes the Grand River from the Dimondale Dam in the village of Dimondale (Mile 164.1) to the Grand Ledge Dam in the city of Grand Ledge (Mile 138.5); the Red Cedar River from its confluence with the Grand River to the Michigan State University Dam (Mile 5.6); and Sycamore Creek from its mouth to the Holt Road Bridge (Mile 9.3). The reach of the Grand River flows from Dimondale northeast to Lansing, thence west to Grand Ledge. The Grand River traverses a distance of 25.6 miles measured along the river. The Red Cedar River flows westward through Lansing, thence southwest to Sycamore Creek, thence northwest to its confluence with the Grand River in Lansing. The total reach of the Red Cedar River is 5.6 miles. Sycamore Creek flows generally from south to north a distance of 9.3 miles. These river reaches and their associated flood plains have been subjected to floods of 11 to 15 feet above low water. The flood duration has averaged 5 days above the damage stage. Flood plain information for this area is reported in "Flood Plain Information, Grand River, Red Cedar River, and Sycamore Creek, Ingham and Eaton Counties, Michigan, by Corps of Engineers, U.S. Army, Detroit District - 1969".

b. Red Cedar River. This study area extends from the Michigan State University Dam in the city of East Lansing at river mile 516 to the Straight Dam in the city of Williamston at river mile 21.6, a distance of 16.0 river miles. The general direction of flow is west by north. This river reach and its flood plains have been subjected to the same river rises as the Red Cedar River reach discussed in Study A. Study B is reported upon in "Flood Plain Information, Red Cedar River, Ingham County, Michigan, by Corps of Engineers, U.S. Army, Detroit District, March 1968," Johnson & Anderson.

c. Upper Grand River. This study covers the Grand River from Dimondale Dam upstream (south) to the county line between Ingham and Jackson counties, a distance of 27.8 river miles. The city of Eaton Rapids, the village of Dimondale, and the townships of Windsor, Eaton Rapids and Hamlin of Eaton County and the townships Delhi, Aurelius and Onondaga of Ingham County are in the basin of this reach of the Grand River. This river reach and its flood plain have been subjected to floods of 4 feet over the bank-full stage. The water has been above the bank-full stage for as long as 22 days. This study is reported upon in "Flood Plain Information, Grand River, Ingham County and Eaton Counties, Michigan, by Corps of Engineers, U.S. Army, Detroit District - 1969".

d. Lookingglass River. This study covers the Lookingglass River from the Ionia-Clinton County Line upstream to the Clinton-Shiawassee County Line, a distance of 30 miles along the river. A contract has been awarded to Hubbel, Roth and Clark, Inc., to make this study and to furnish a report.

53. REQUESTED STUDIES IN BASIN NOT NOW APPROVED OR FUNDED. The Michigan Water Resources Commission has made 18 additional applications for flood plain information studies in the Grand River Basin in addition to the preceding four outlined. The streams' locations, length of the reaches, Basin priority of study as of July 1968, and requesting local governmental agency are presented in Table H-28. These listings have been referred to the Chief of Engineers for approval and to initiate funding action and scheduling, as applicable.

TABLE H-28

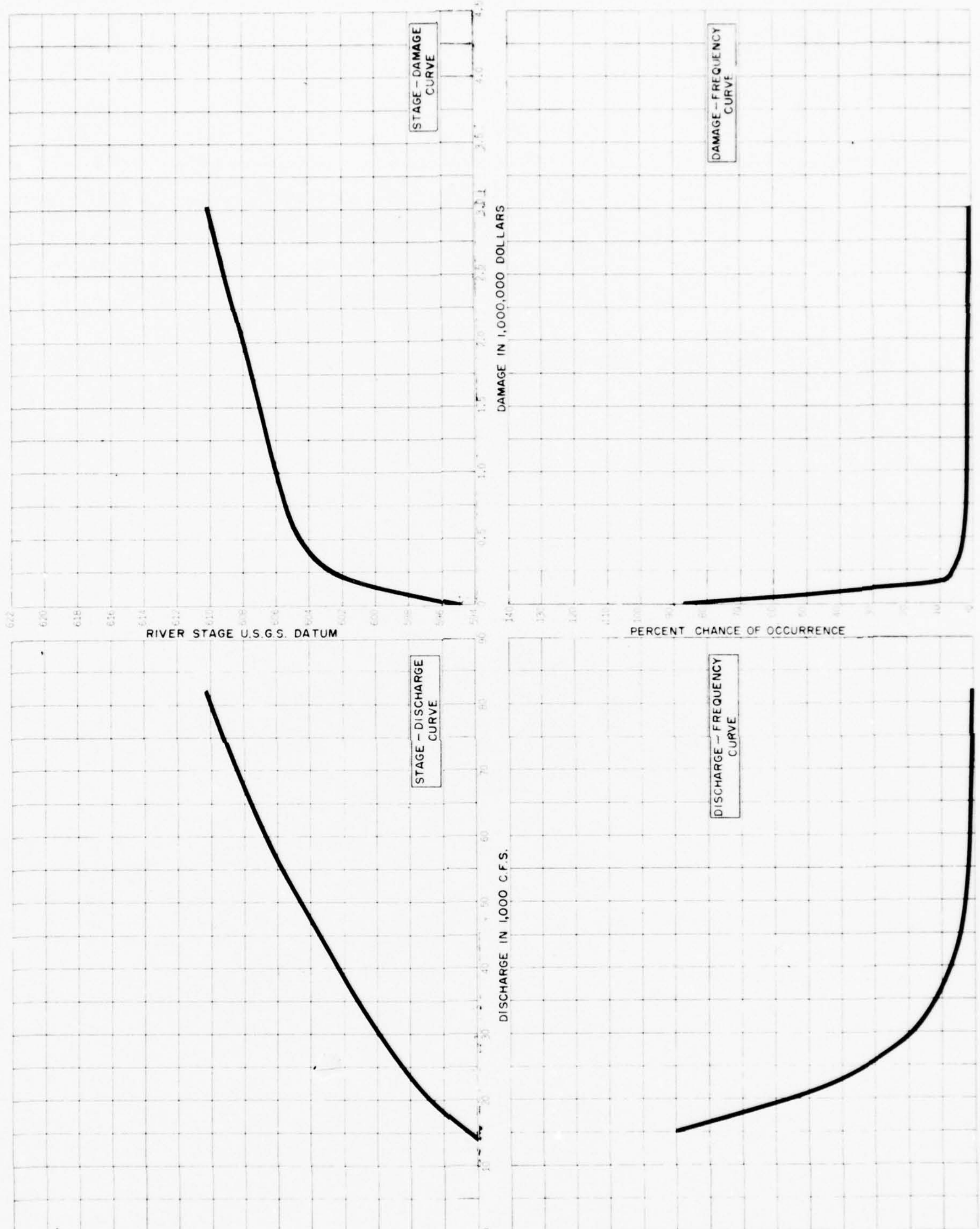
APPLICATIONS FOR FLOOD PLAIN INFORMATION STUDIES
GRAND RIVER BASIN

Basin Priority and Name of Study	Stream Location and Approx. Length of Reach in Study Area	Agency Sponsoring Study
1 - Grand Rapids	Grand River - From north city limits of Grand Rapids to the west city limits of Walker and Grandville, Kent County; 12 miles long.	MGRWC
2 - Grandville-Wyoming	Buck Creek - From Clyde Park and 76th Street in Byron Township through Wyoming and Grandville to the Grand River, Kent County; 11 miles.	"
3 - Wyoming-Kentwood-Grand Rapids	Plaster Creek - From 52nd Street through Kentwood, Grand Rapids and Wyoming to the Grand River, Kent County; 11 miles	"
4 - Ionia	Grand River - From the east city limits of Ionia to the west city limits, Ionia County; 2 miles.	"
5 - Portland	Grand River and Lookingglass River - Grand River from south city limits of Portland to north city limits. Lookingglass River from east city limits of Portland to Grand River, Ionia County; 3 miles.	"
6 - Lowell	Grand River - From the Kent-Ionia County line through the city of Lowell to the west city limits, Kent County; 2 miles.	"
7 - Hastings	Thornapple River - From Center Road through the city of Hastings to the west city limits, Barry County; 3 miles.	"
8 - Jackson	Grand River - From the Probert Road bridge and from Sharpes Lake downstream through Jackson to the confluence with the Portage River, Jackson County; 13 miles.	"

TABLE H-28 (Cont'd)

9 - Michigan Center	North Branch Grand River - From Center Lake in Michigan Center to the Grand River, Jackson County; 3 miles.	MGRWC
10 - Greenville	Flat River - From the north city limits of Greenville to the south city limits, Montcalm County; 3 miles.	"
11 - Saranac	Grand River - From the east line of section 1 to the west line of section 2, all in Boston Township, through the Village of Saranac, Ionia County; 2 miles.	"
12 - Belding	Flat River - From the north line of section 12, through the city of Belding to the south city limits, Ionia County; 4 miles.	"
13 - Rockford	Rogue River - From the north city limits of Rockford to the Childsdale Avenue Bridge, Kent County; 3 miles.	"
14 - Middleville	Thornapple River - From the south line of section 26, through the village of Middleville to the north line of section 22, Barry County; 2 miles.	"
15 - Nashville	Thornapple River - From the east village limits of Nashville to the west village limits, Barry County; 2 miles.	"
16 - Mason	Sycamore Creek and Mud Creek - Sycamore Creek from Holt Road to Tomlinson Road, Alaiedon and Vevay Townships in Ingham County; 9 miles.	TCRPC
17 - Red Cedar-East Ingham Co.	Red Cedar - From Williamston to the Ingham-Livingston County Line, Ingham County; 9 miles.	"
18 - Grand Ledge	Grand River - From Clinton-Ionia County Line to Grand Ledge Dam, Clinton and Eaton Counties; 6 miles.	"

MGRWC = Michigan Grand River Watershed Council
TCRPC = Tri-County Regional Planning Commission



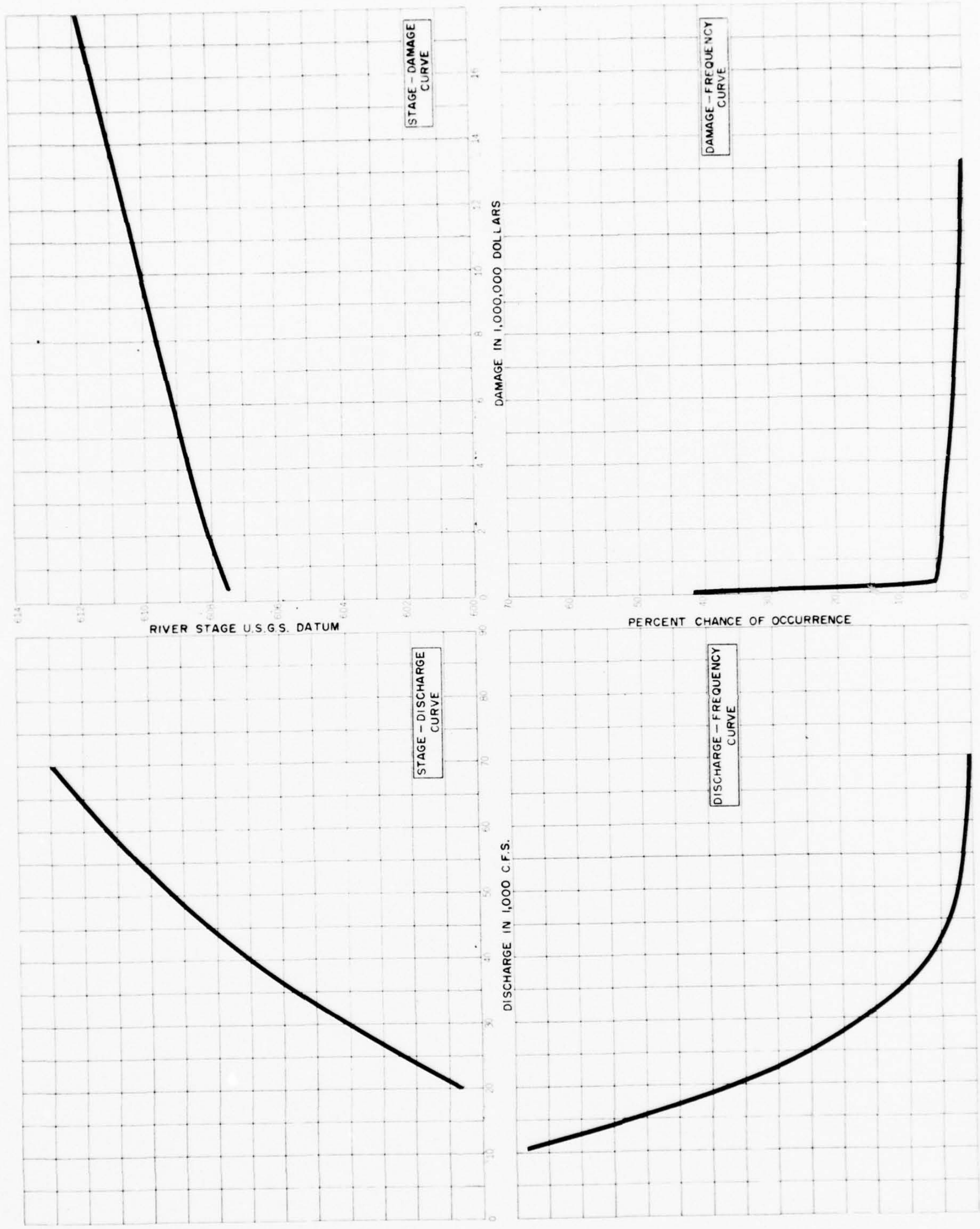
GRAND RIVER BASIN, MICHIGAN

ECONOMIC EVALUATION

GRANDVILLE

U.S. ARMY ENGINEER DISTRICT, DETROIT

FIGURE H-1



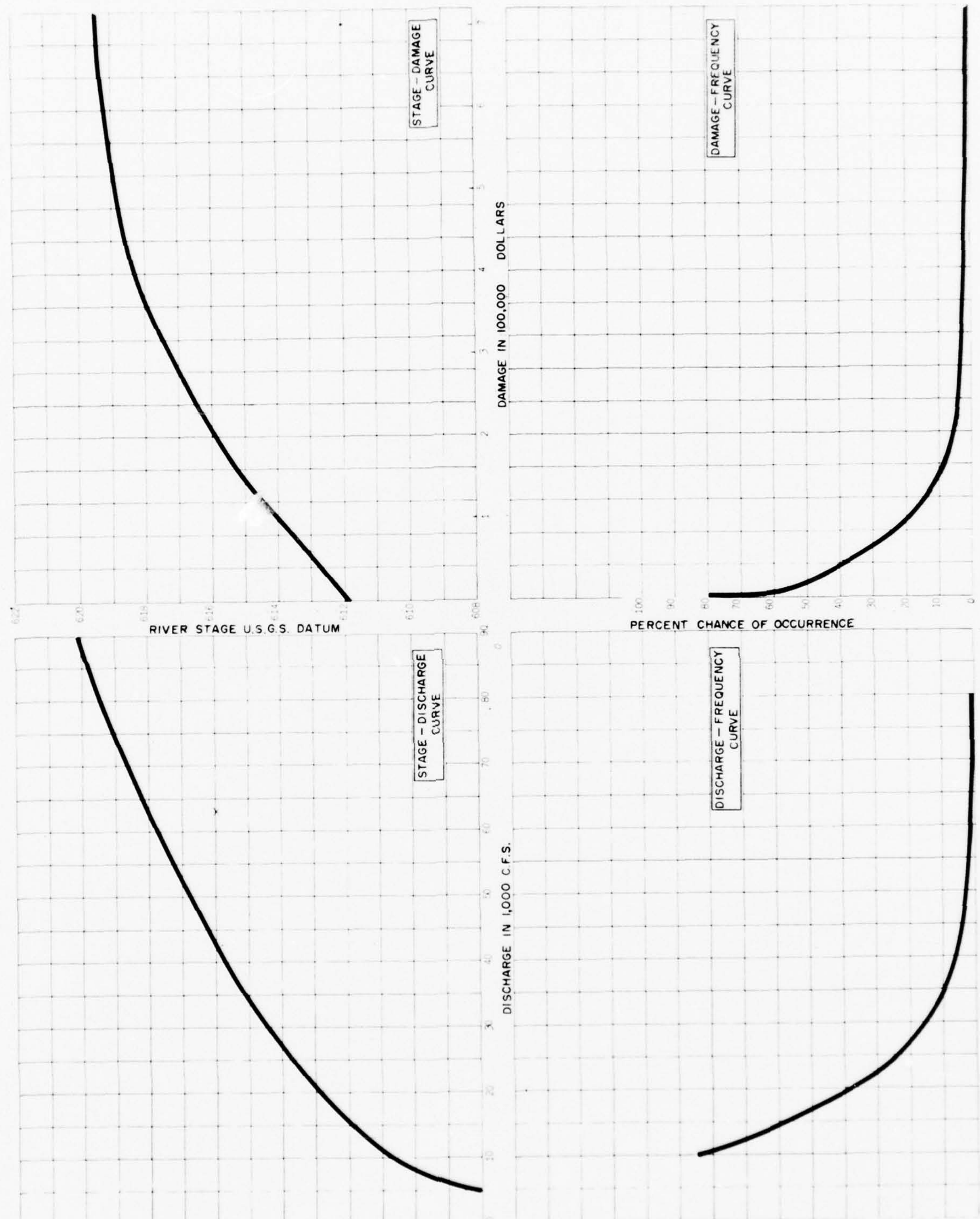
GRAND RIVER BASIN, MICHIGAN

ECONOMIC EVALUATION

GRAND RAPIDS

U.S. ARMY ENGINEER DISTRICT, DETROIT

FIGURE H-2



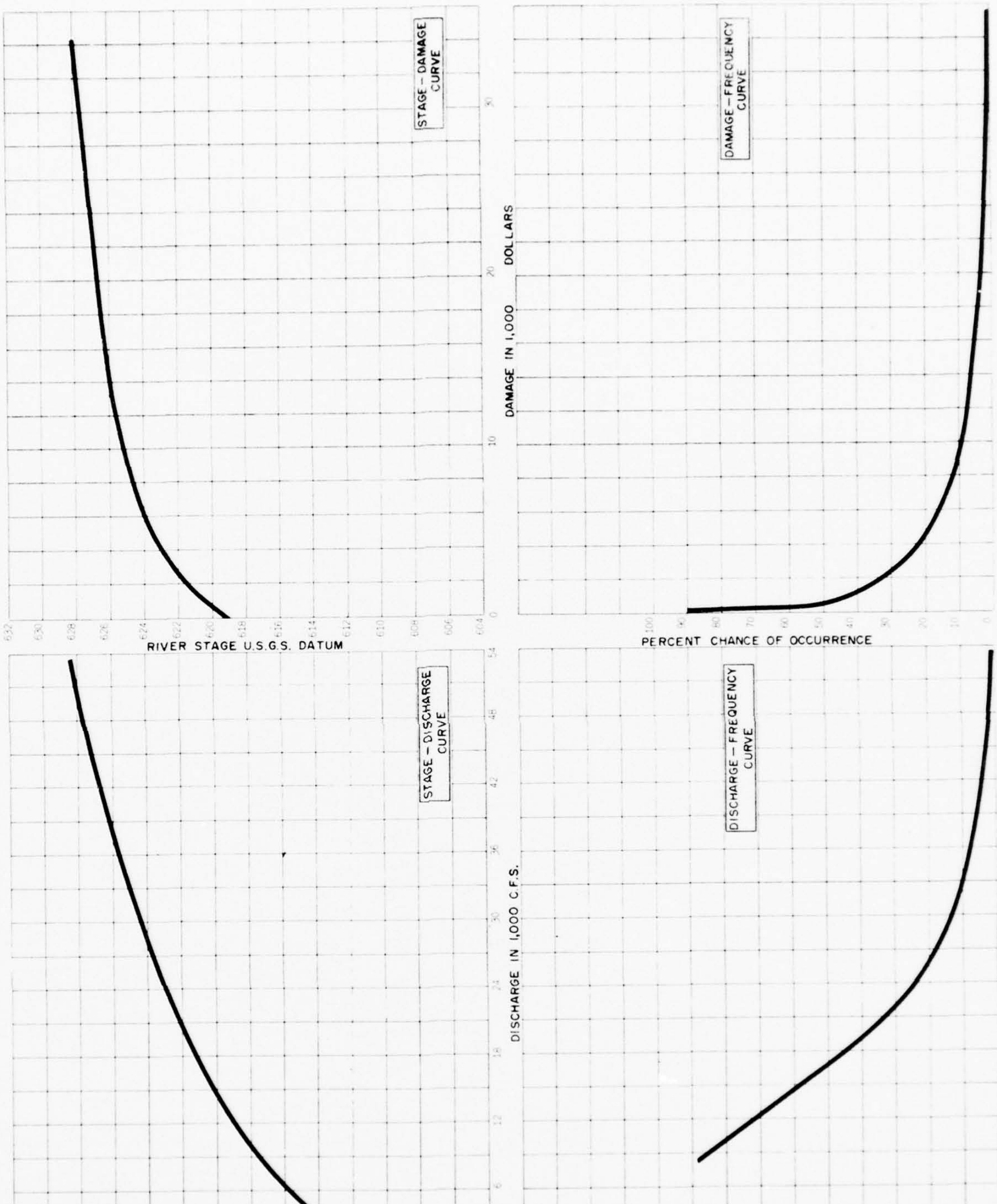
GRAND RIVER BASIN, MICHIGAN

ECONOMIC EVALUATION

PLAINFIELD TOWNSHIP

U.S. ARMY ENGINEER DISTRICT, DETROIT

FIGURE H-3



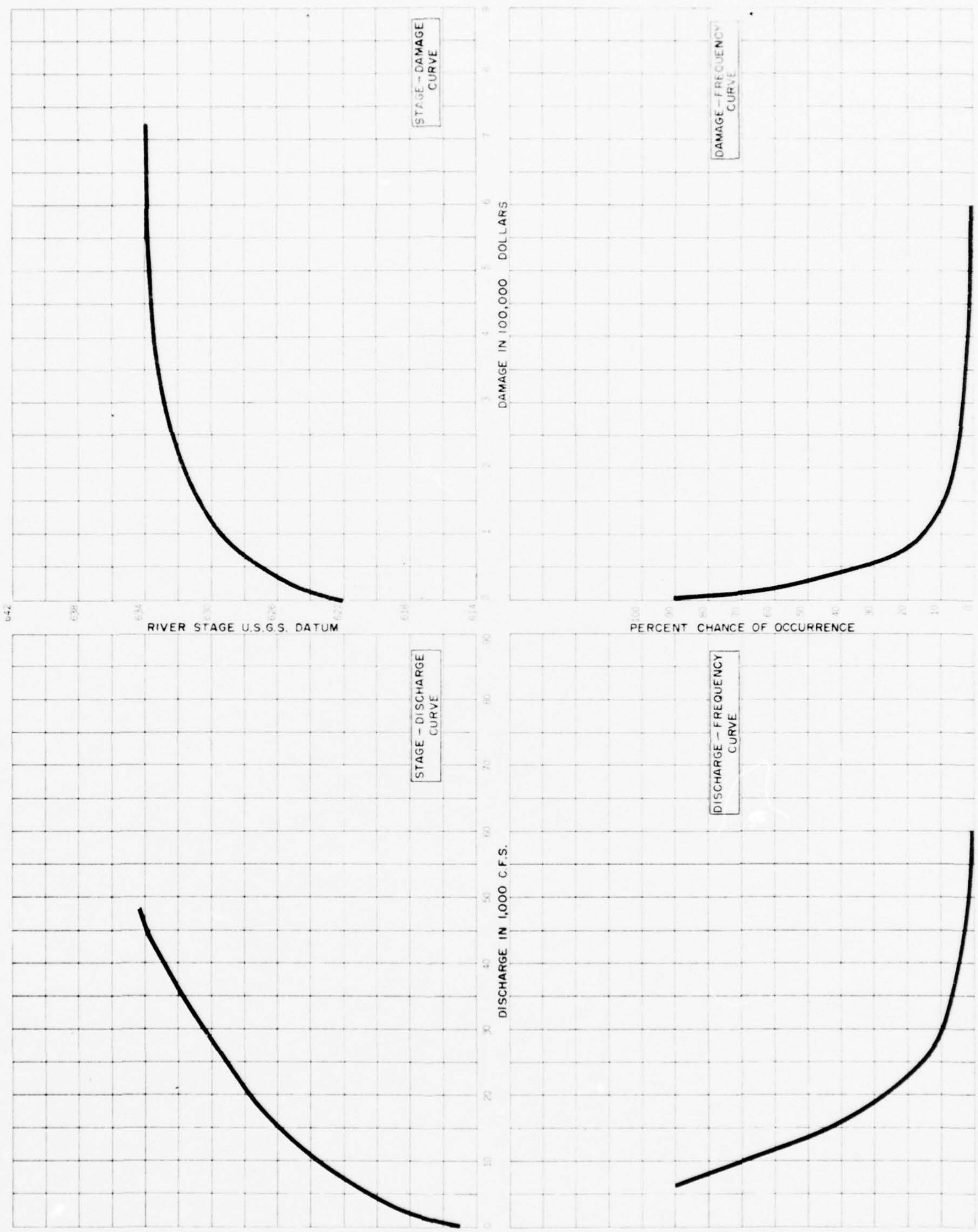
GRAND RIVER BASIN, MICHIGAN

ECONOMIC EVALUATION

ADA

U.S. ARMY ENGINEER DISTRICT, DETROIT

FIGURE H-4



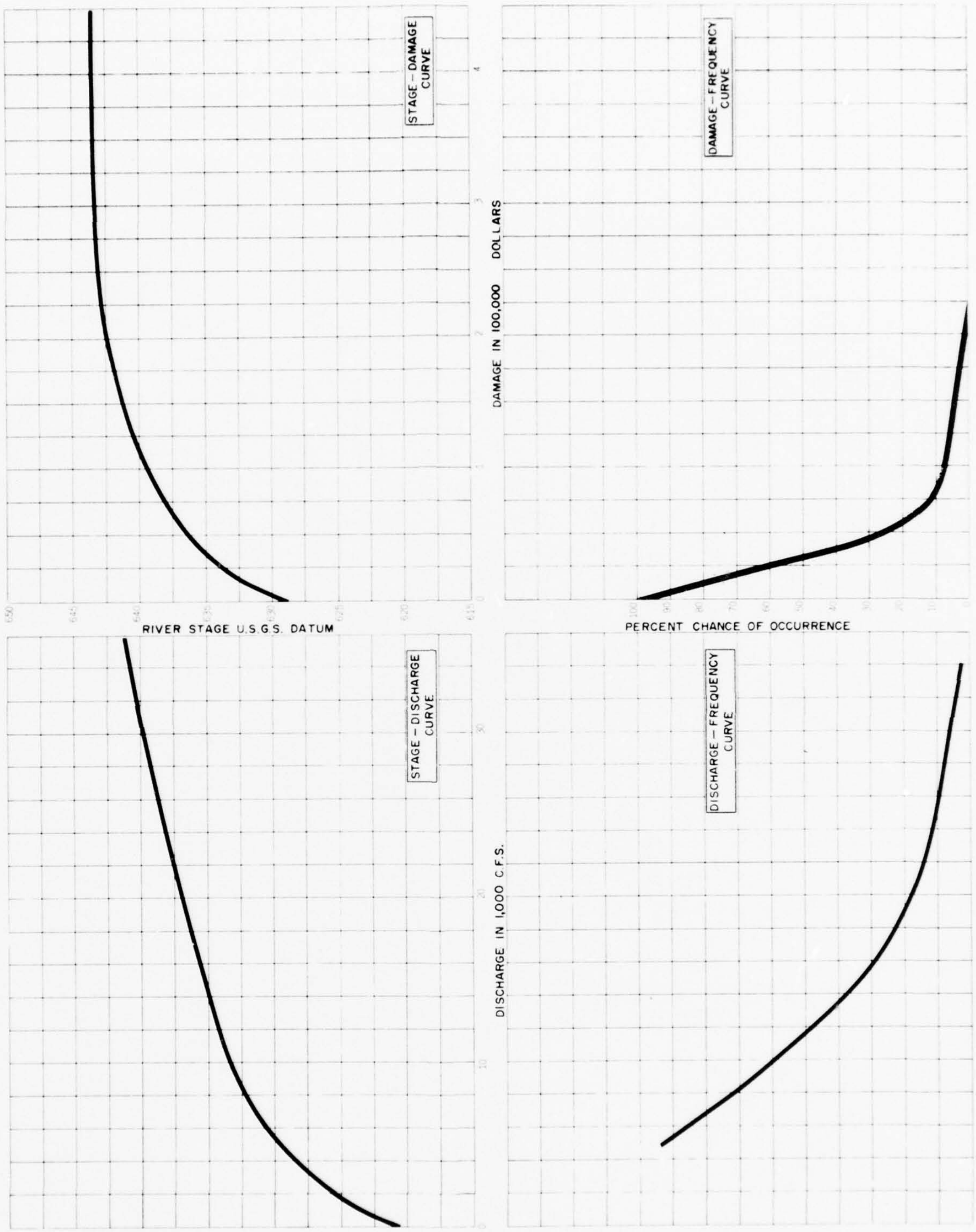
GRAND RIVER BASIN, MICHIGAN

ECONOMIC EVALUATION

LOWELL

U.S. ARMY ENGINEER DISTRICT, DETROIT

FIGURE H-5



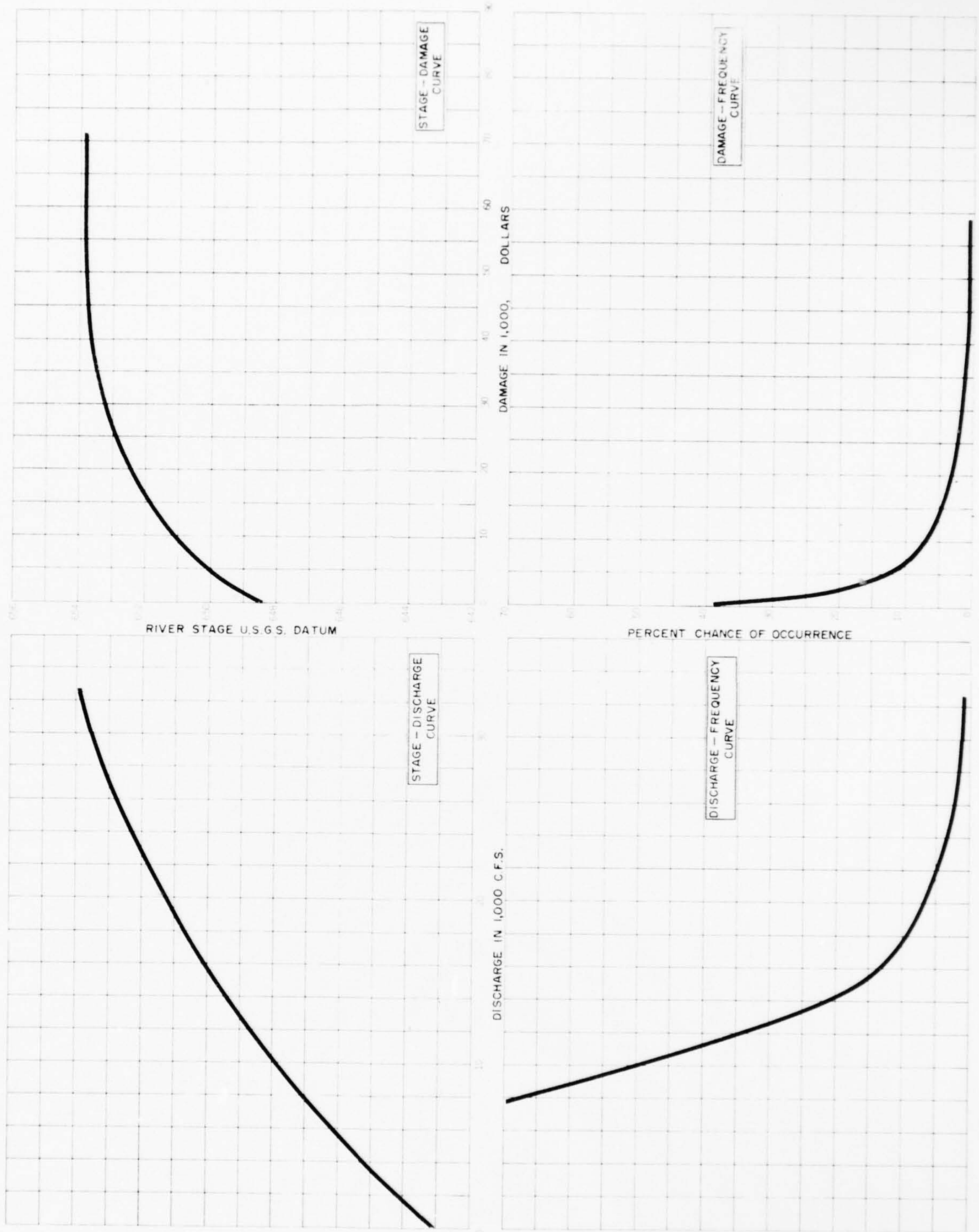
GRAND RIVER BASIN, MICHIGAN

ECONOMIC EVALUATION

IONIA

U.S. ARMY ENGINEER DISTRICT, DETROIT

FIGURE H-6



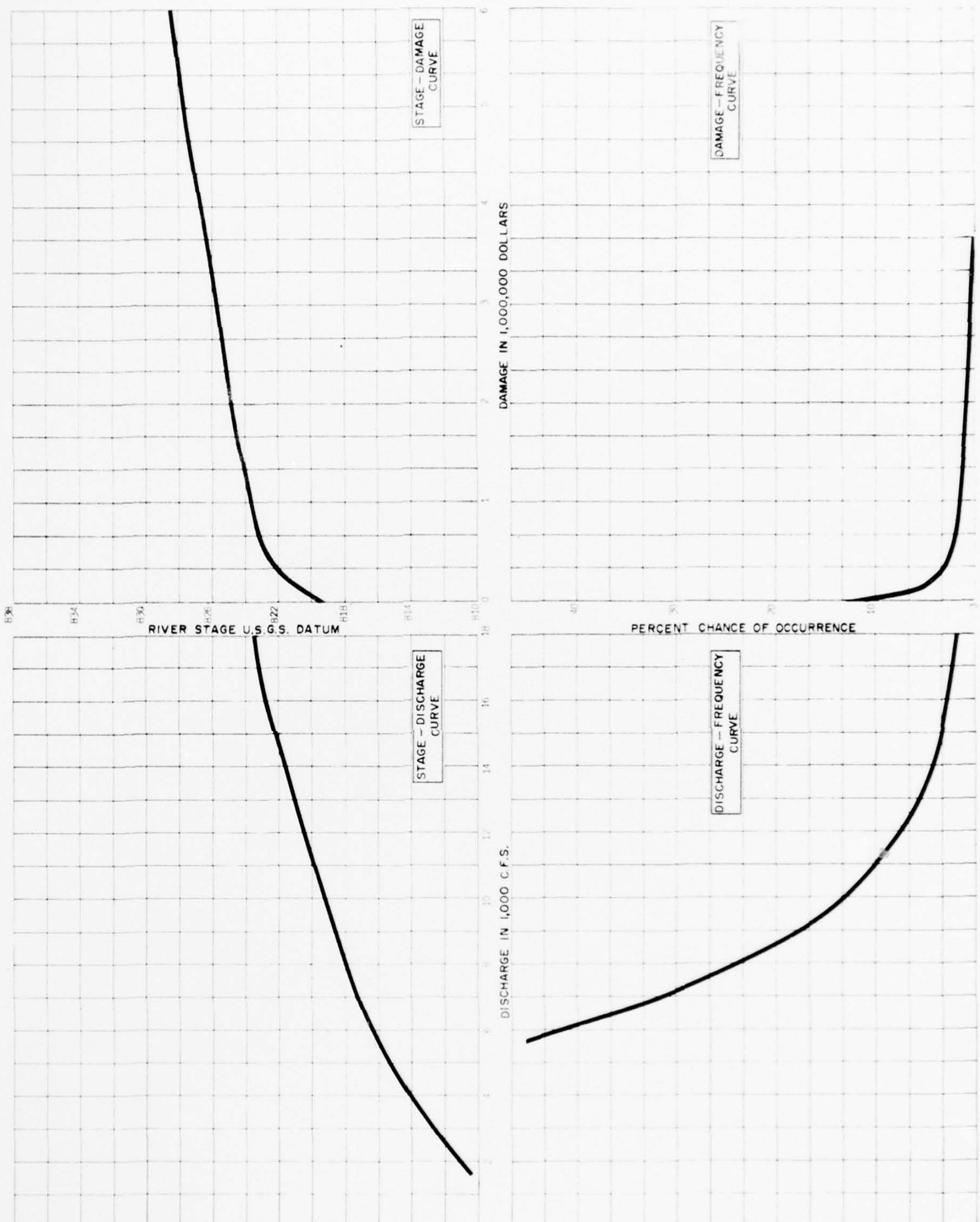
GRAND RIVER BASIN, MICHIGAN

ECONOMIC EVALUATION

LYONS

U.S. ARMY ENGINEER DISTRICT, DETROIT

FIGURE H-7



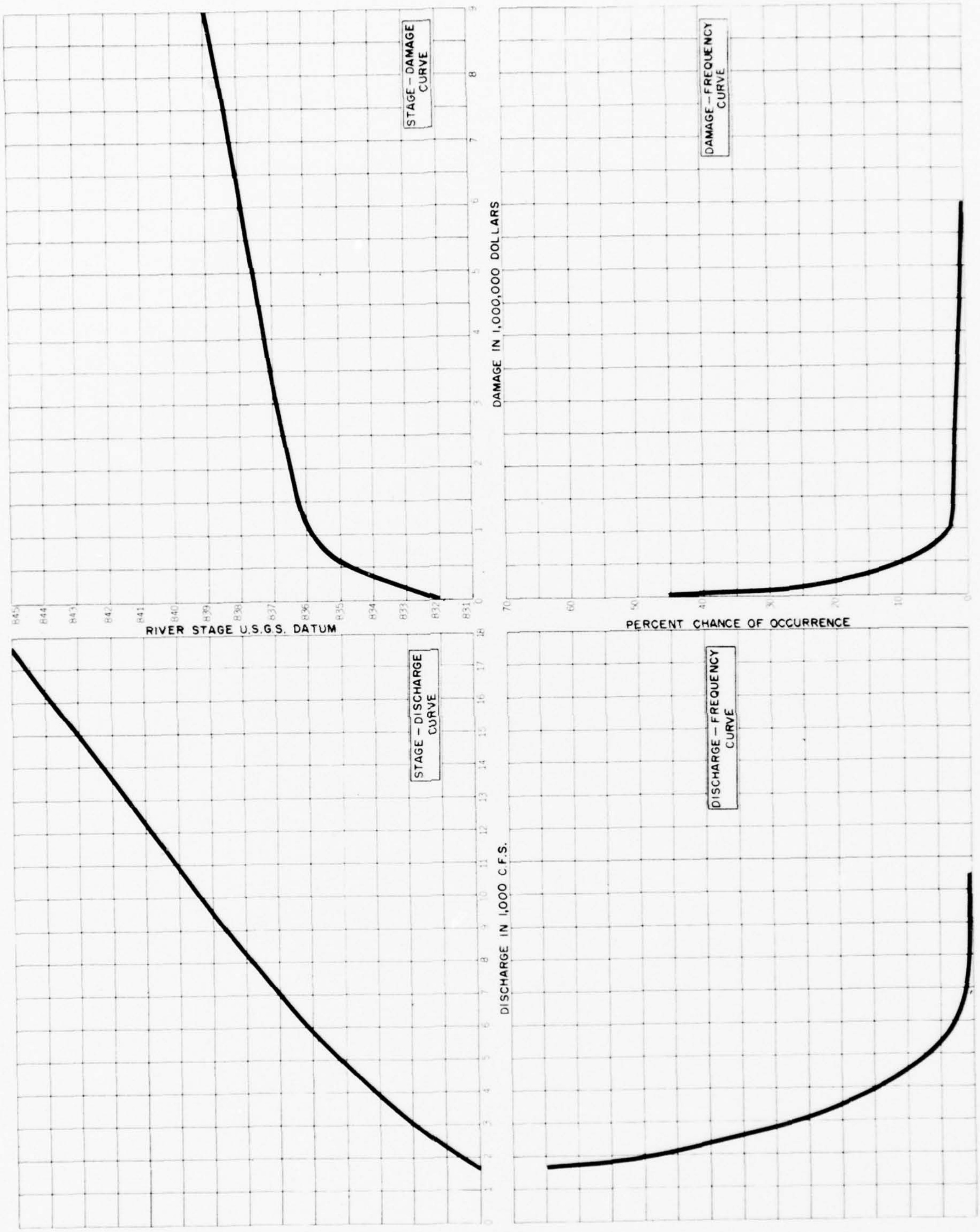
GRAND RIVER BASIN, MICHIGAN

ECONOMIC EVALUATION

LANSING

U.S. ARMY ENGINEER DISTRICT, DETROIT

FIGURE H-8



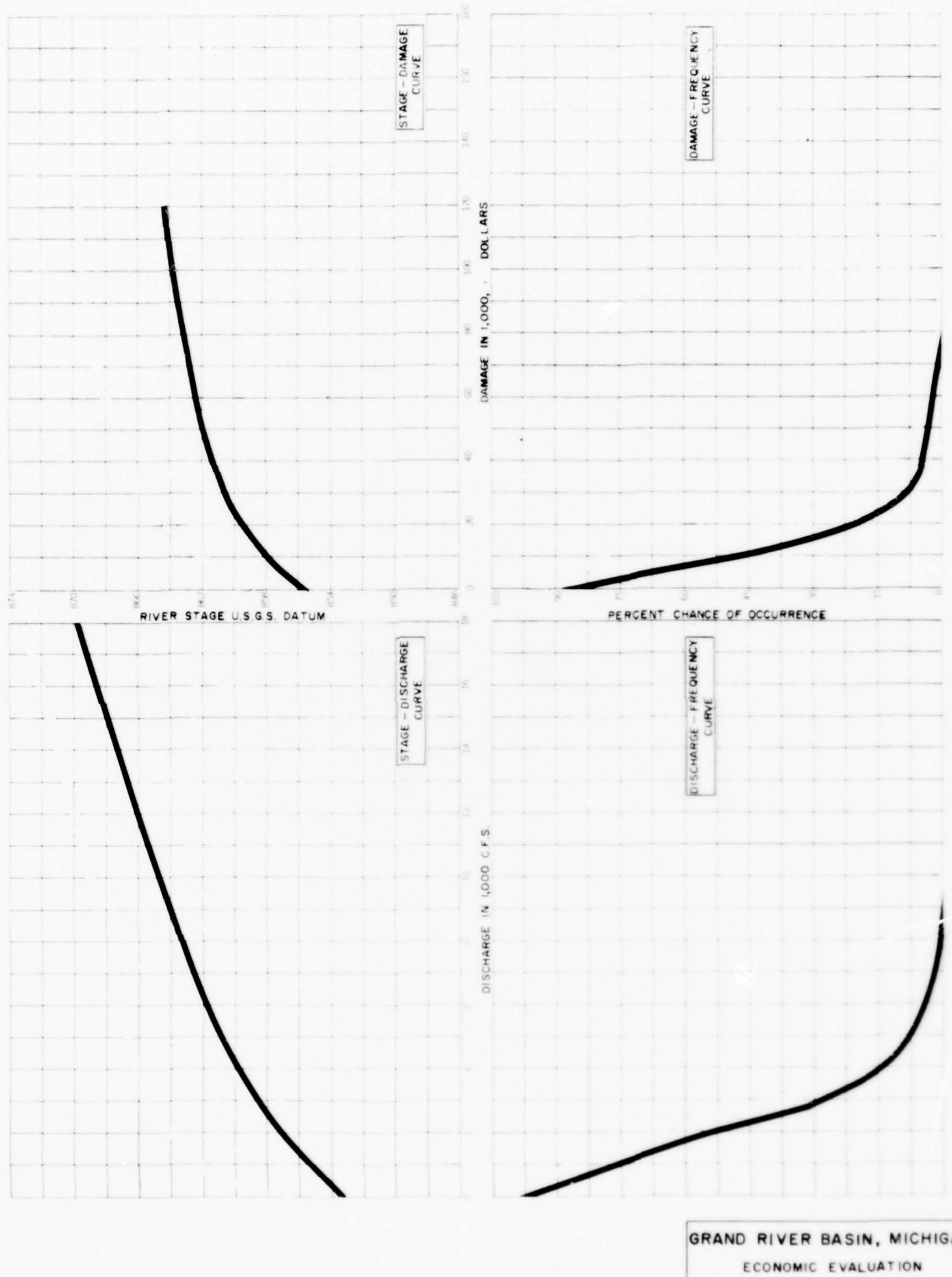
GRAND RIVER BASIN, MICHIGAN

ECONOMIC EVALUATION

EAST LANSING

U.S. ARMY ENGINEER DISTRICT, DETROIT

FIGURE H-9



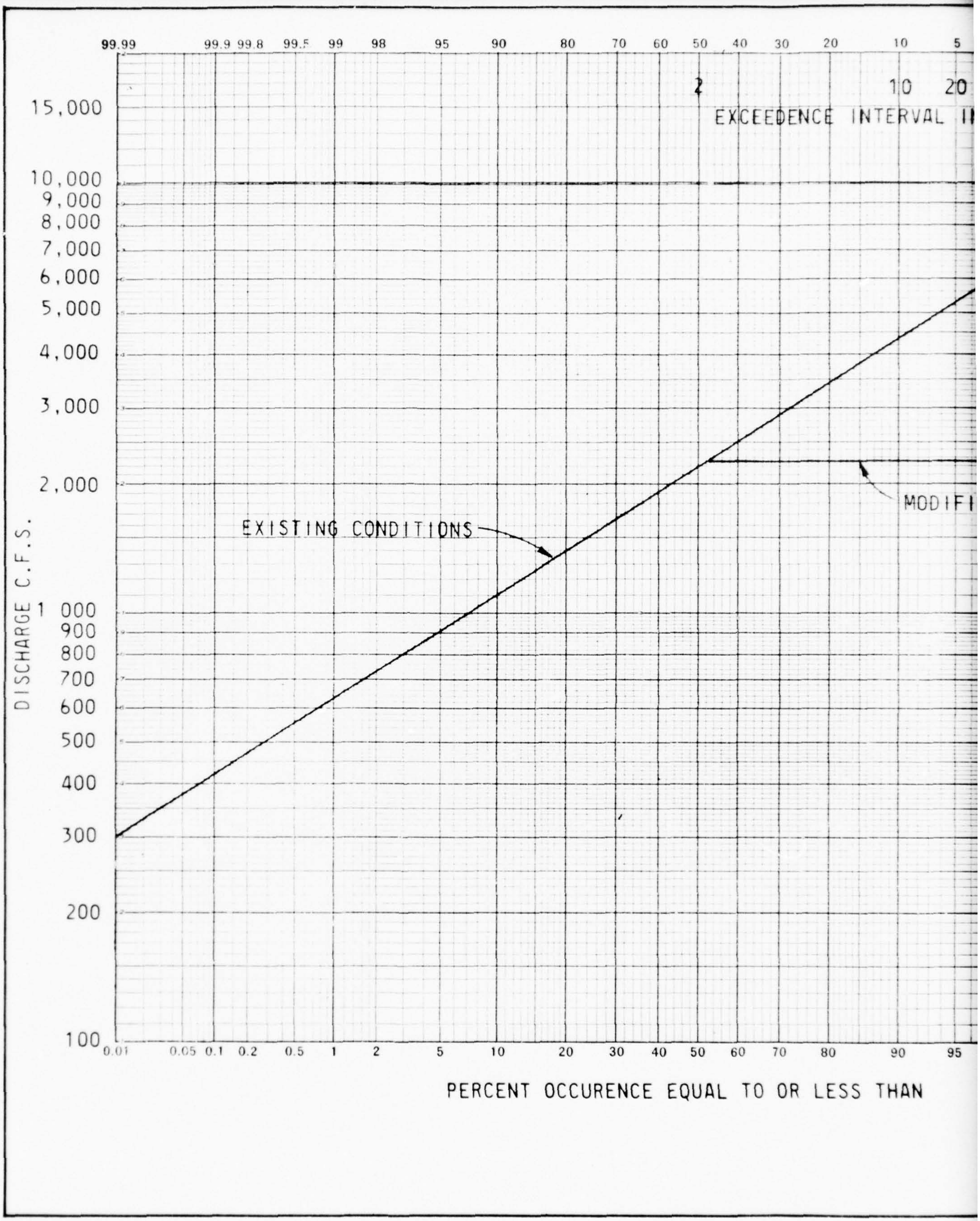
GRAND RIVER BASIN, MICHIGAN

ECONOMIC EVALUATION

EATON RAPIDS

U.S. ARMY ENGINEER DISTRICT, DETROIT

FIGURE H-10



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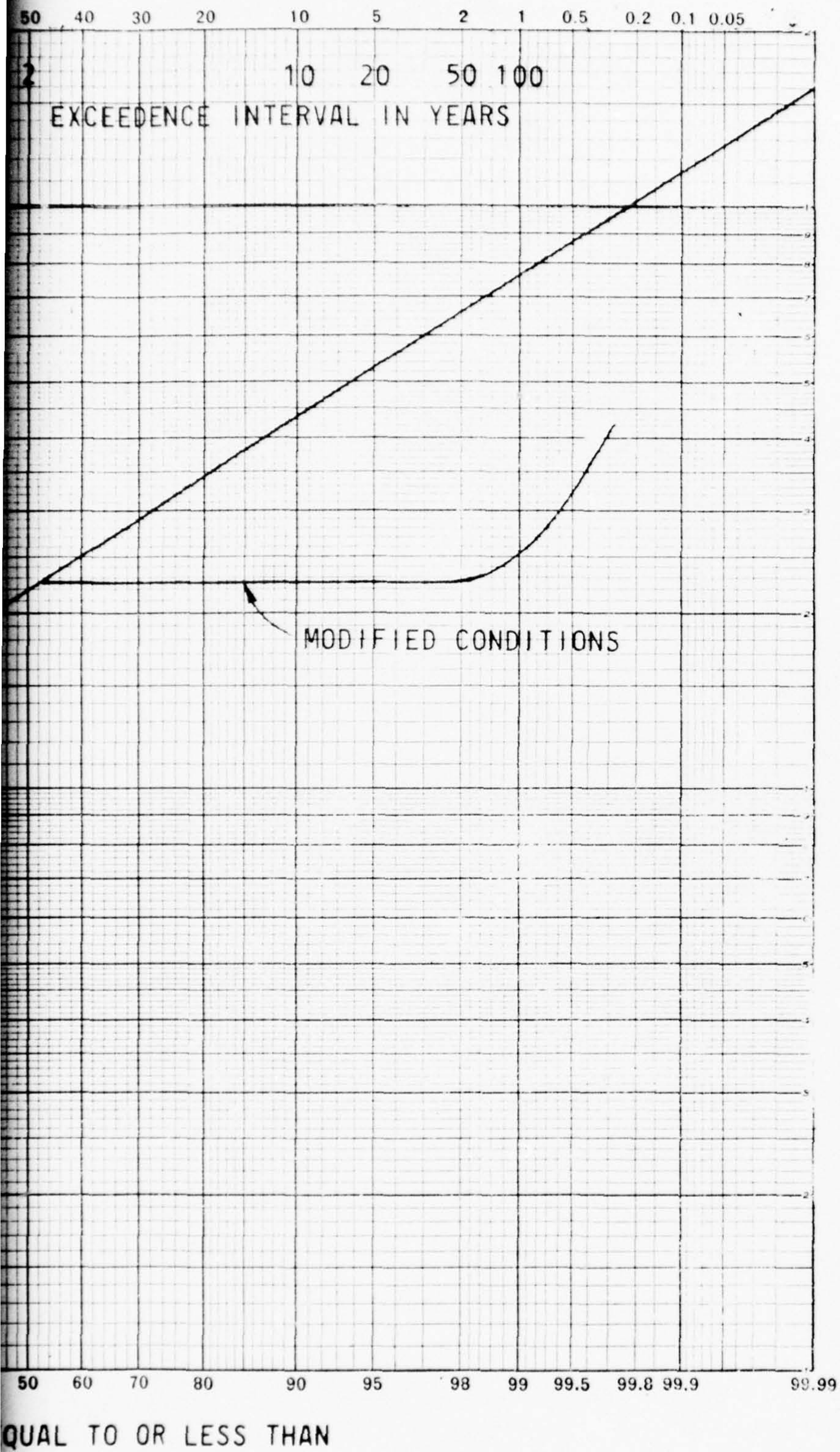
PERCENT OCCURENCE EQUAL TO OR LESS THAN

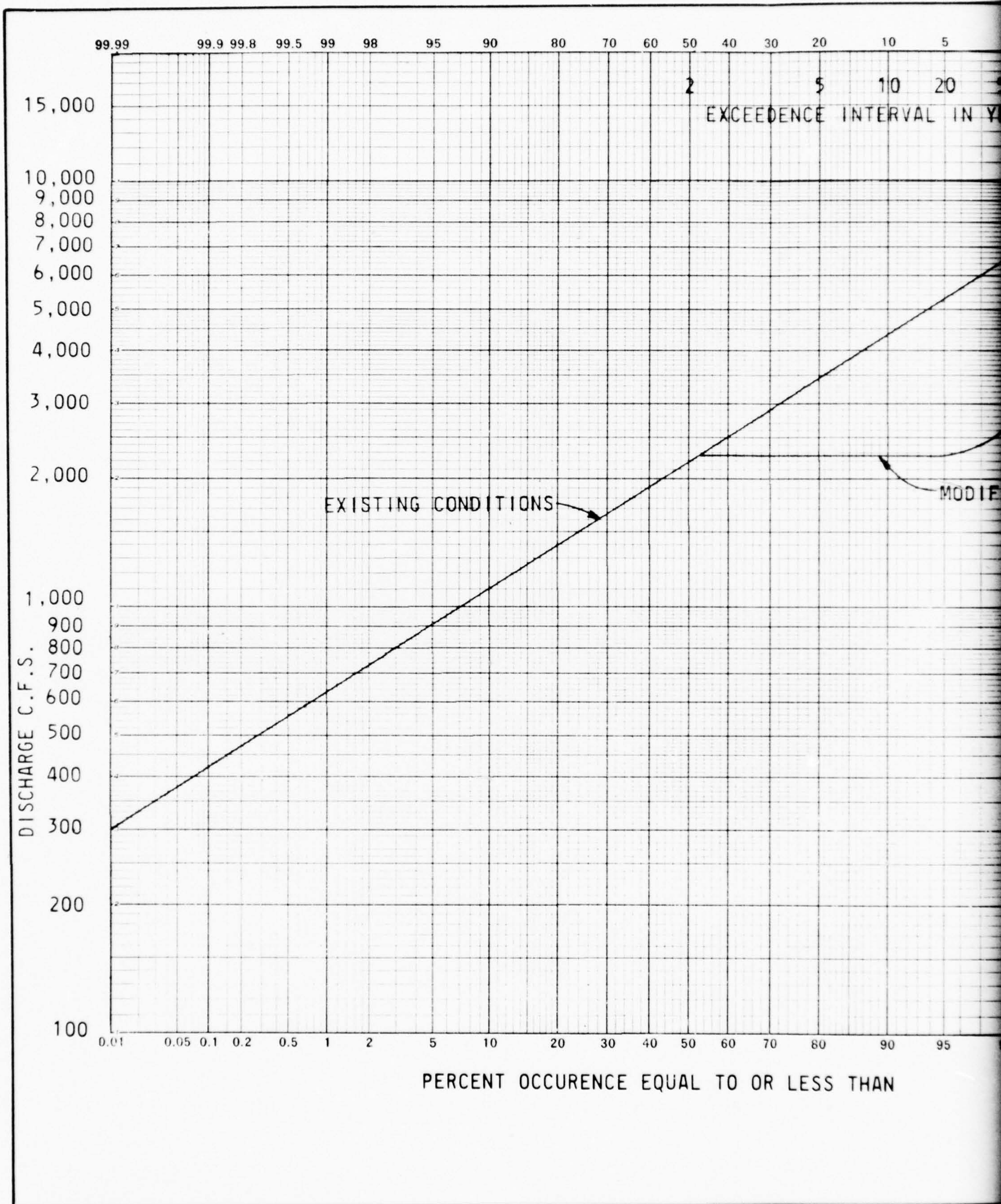


SITE NO.	SITE NAME	COND.	STORAGE
57	OKEMOS		23,000 ACRE FT.

GRAND RIVER BASIN, MICH.
PRELIMINARY RESERVOIR SCREENING
JANUARY 1966

DISCHARGE FREQUENCY OF
RED CEDAR AT EAST LANSING

FIGURE H-11



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DISCHARGE C.F.S.
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MODIF
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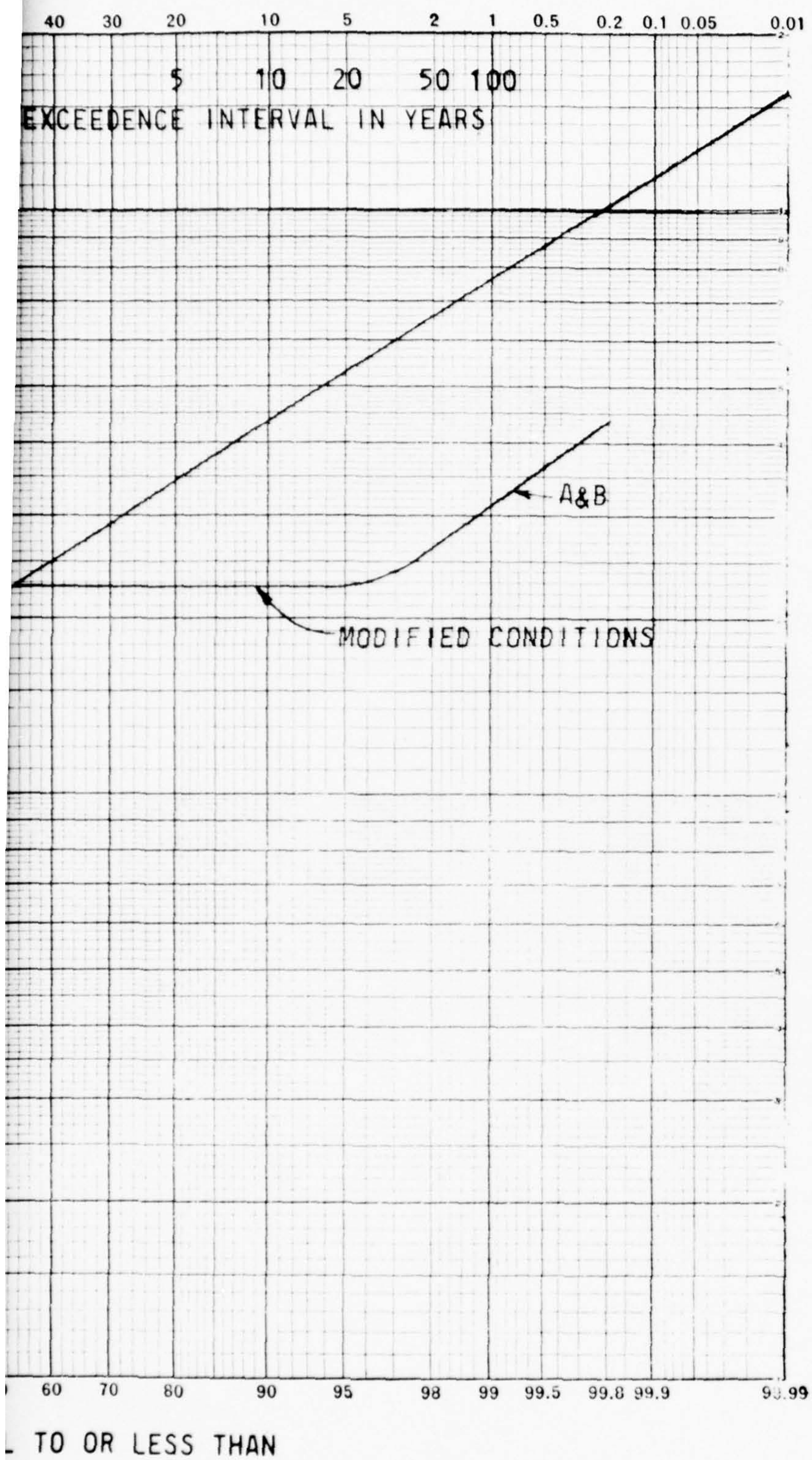
PERCENT OCCURENCE EQUAL TO OR LESS THAN

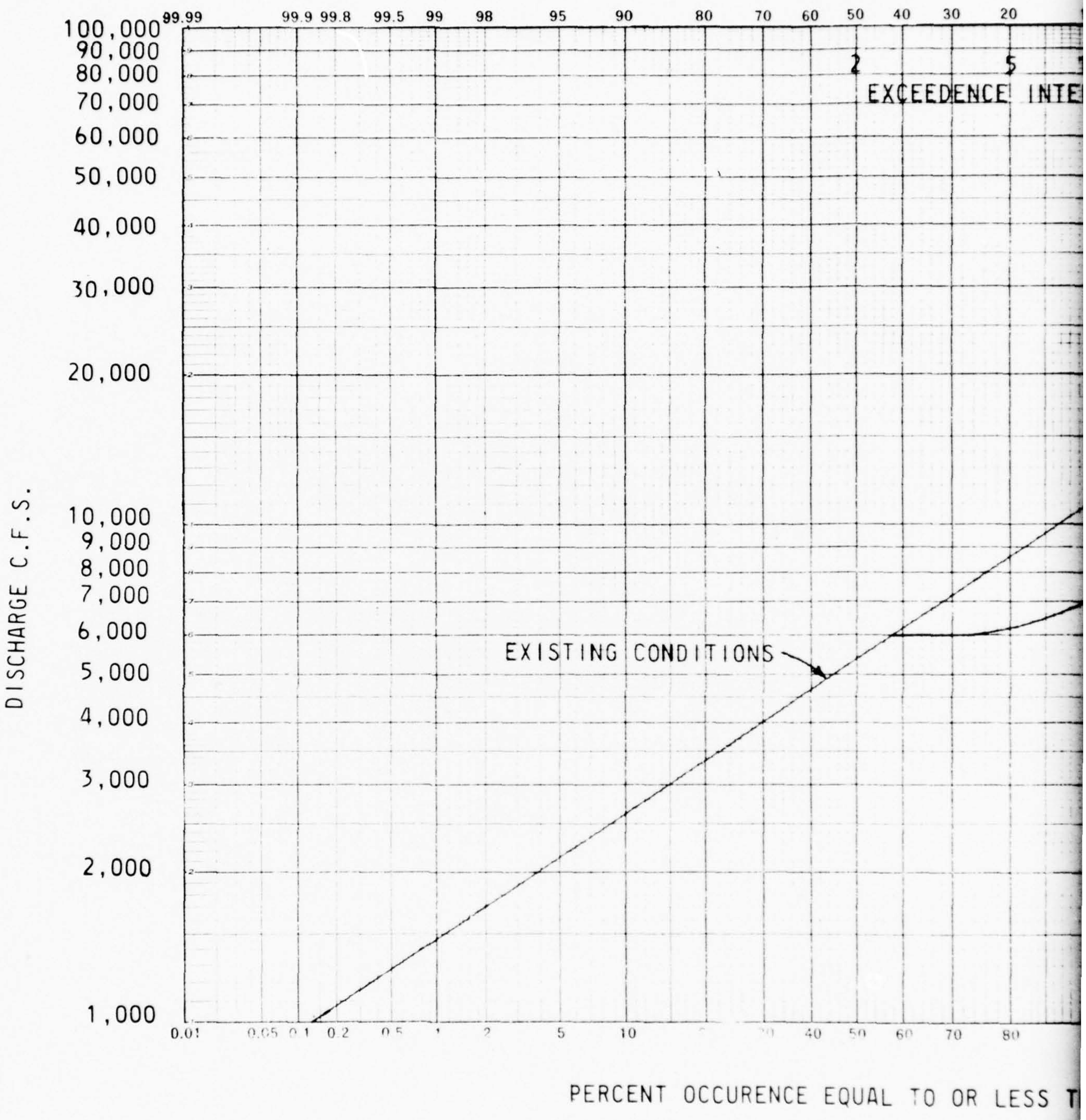


SITE NO.	SITE NAME	COND.	STORAGE
58	WILLIAMSTON	A	67,200 ACRE FT.
		B	16,600 ACRE FT.

GRAND RIVER BASIN, MICH.
PRELIMINARY RESERVOIR SCREENING
JANUARY 1966

DISCHARGE FREQUENCY OF
RED CEDAR AT EAST LANSING

FIGURE H-12



SITE NO.	SITE N
57	OKEMO

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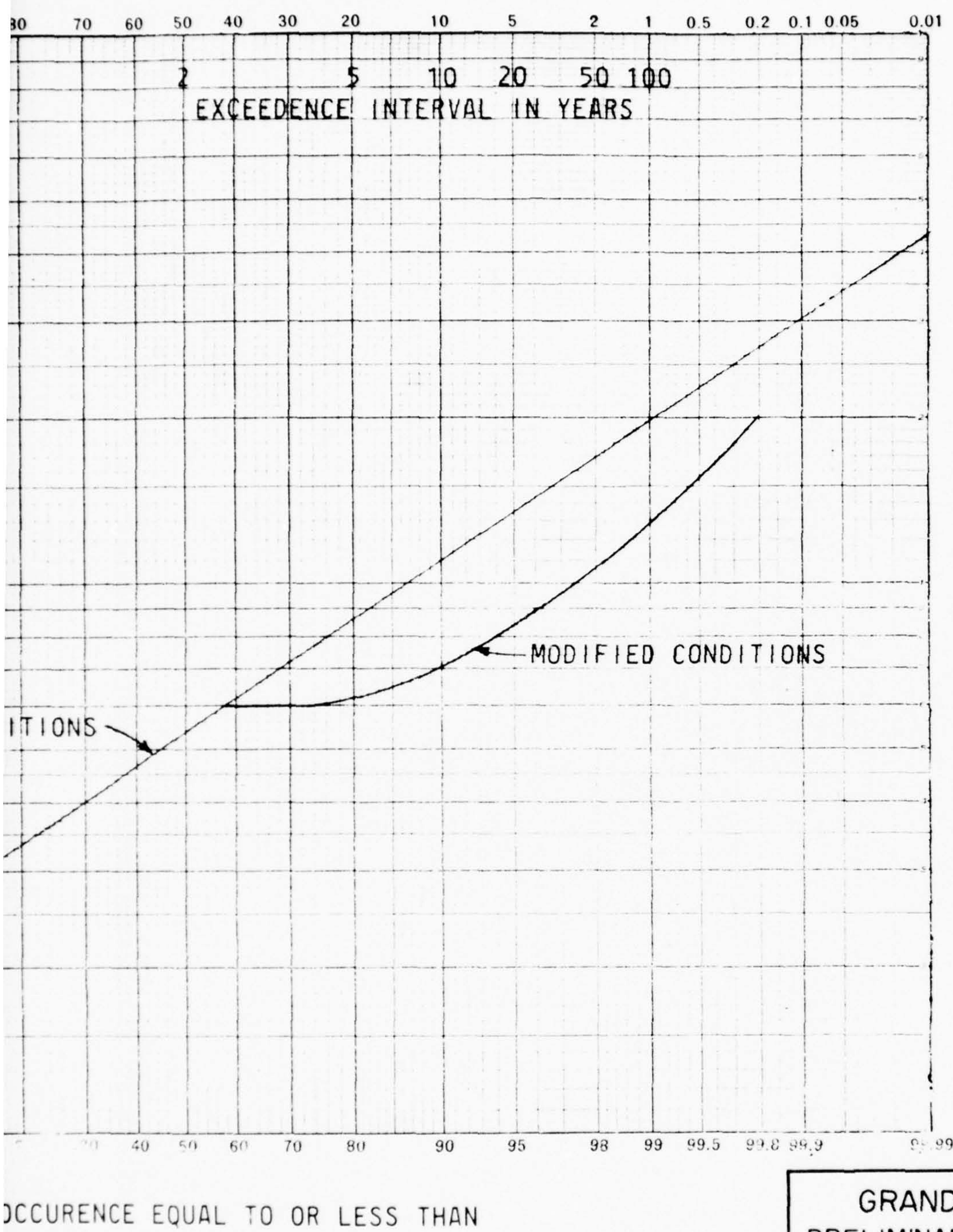
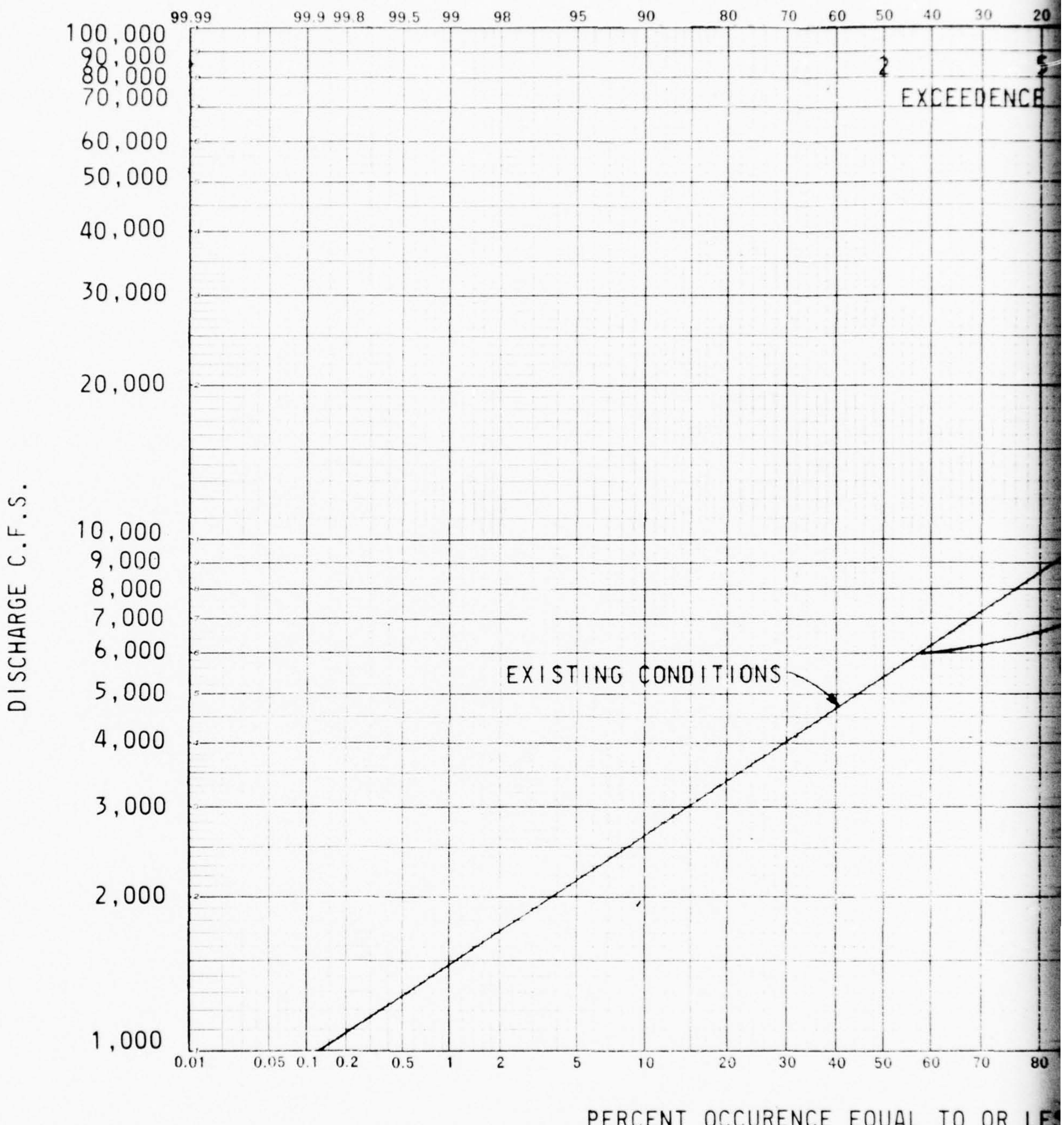


SITE NO.	SITE NAME	COND.	STORAGE
57	OKEMOS		23,800 ACRE FT.

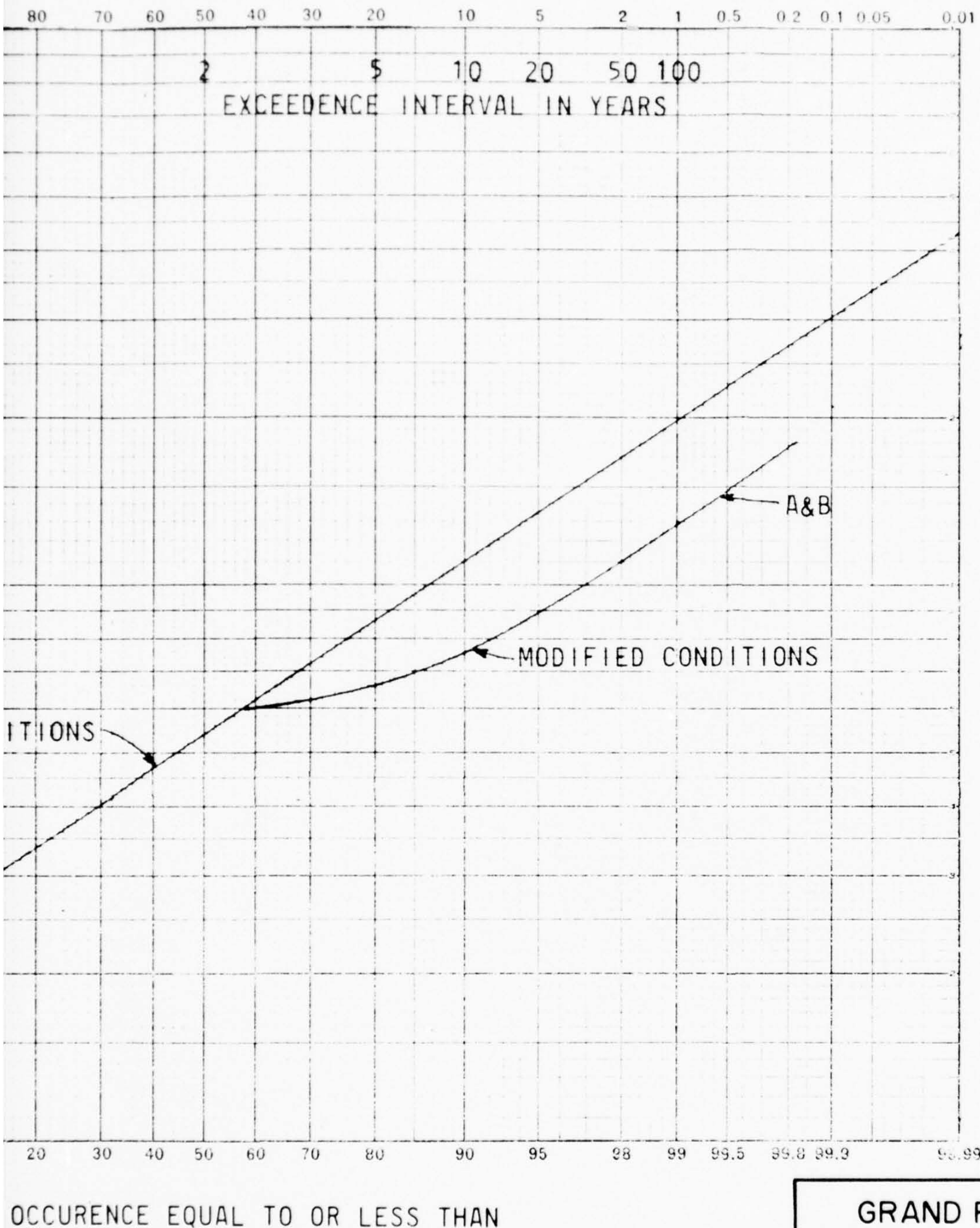
GRAND RIVER BASIN, MICH.
PRELIMINARY RESERVOIR SCREENING
JANUARY 1966

DISCHARGE FREQUENCY OF
GRAND RIVER AT LANSING

FIGURE H-13



SITE NO.	SITE
7	ONO

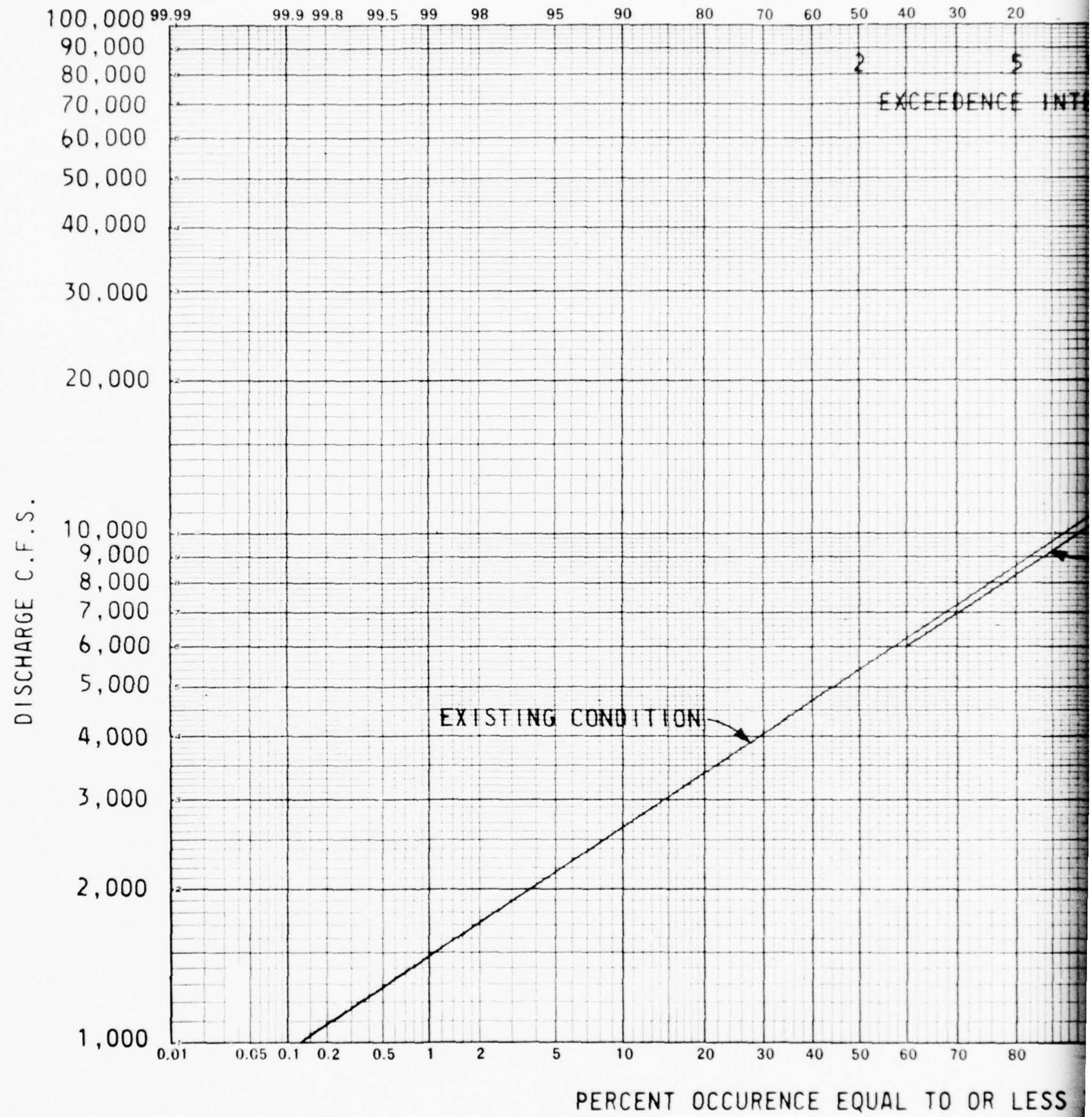


SITE NO.	SITE NAME	COND.	STORAGE
7	ONONDAGA	A	221,300 ACRE FT.
		B	30,600 ACRE FT.

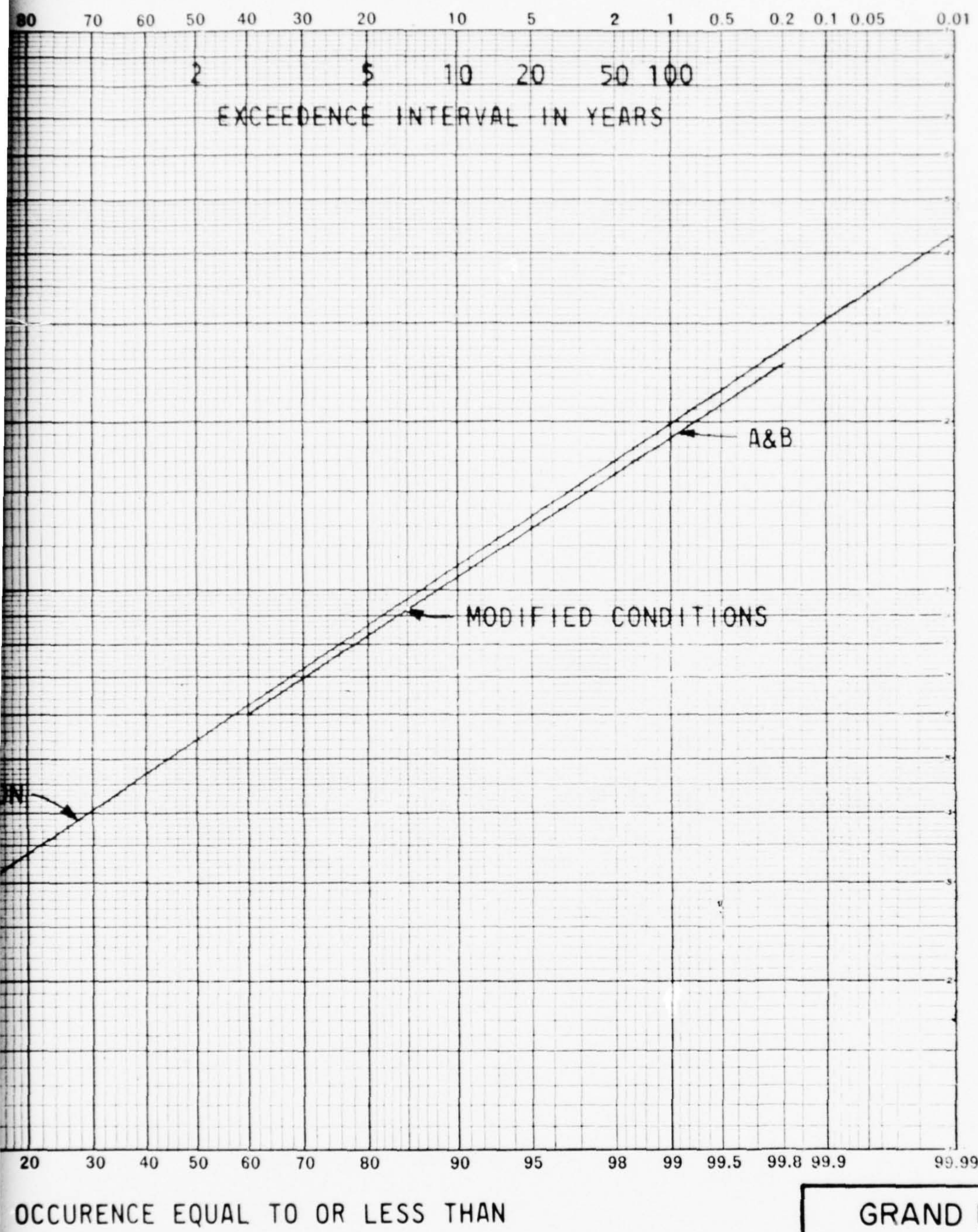
GRAND RIVER BASIN, MICH.
PRELIMINARY RESERVOIR SCREENING
JANUARY 1966

DISCHARGE FREQUENCY OF
GRAND RIVER AT LANSING

FIGURE H-14



SITE NO.	SITE NA
63	PORTAG

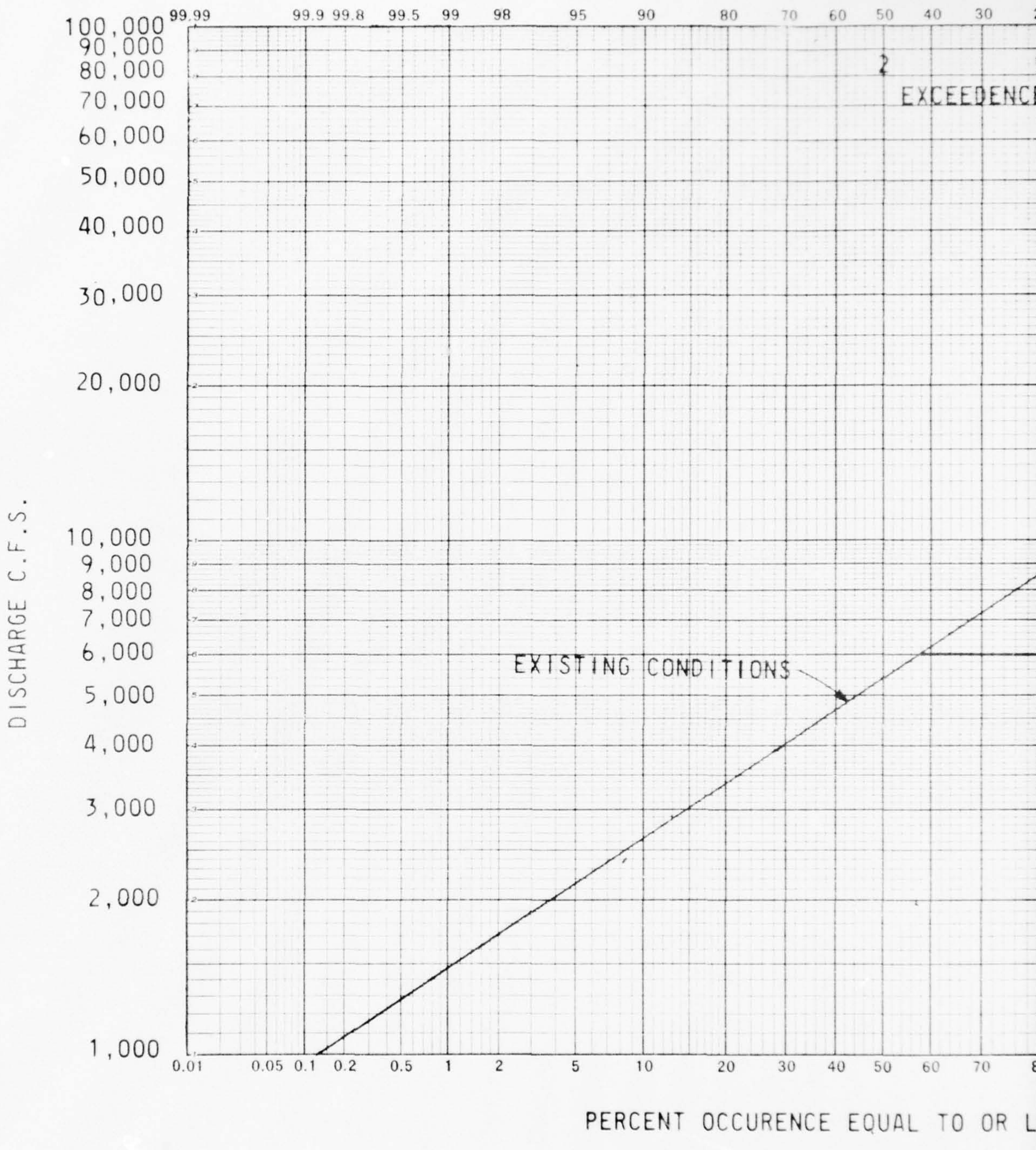


SITE NO.	SITE NAME	COND.	STORAGE
63	PORTAGE	A	20,880 ACRE FT.
		B	3,372 ACRE FT.

GRAND RIVER BASIN, MICH.
PRELIMINARY RESERVOIR SCREENING
JANUARY 1966

DISCHARGE FREQUENCY OF
GRAND RIVER AT LANSING

FIGURE H-15



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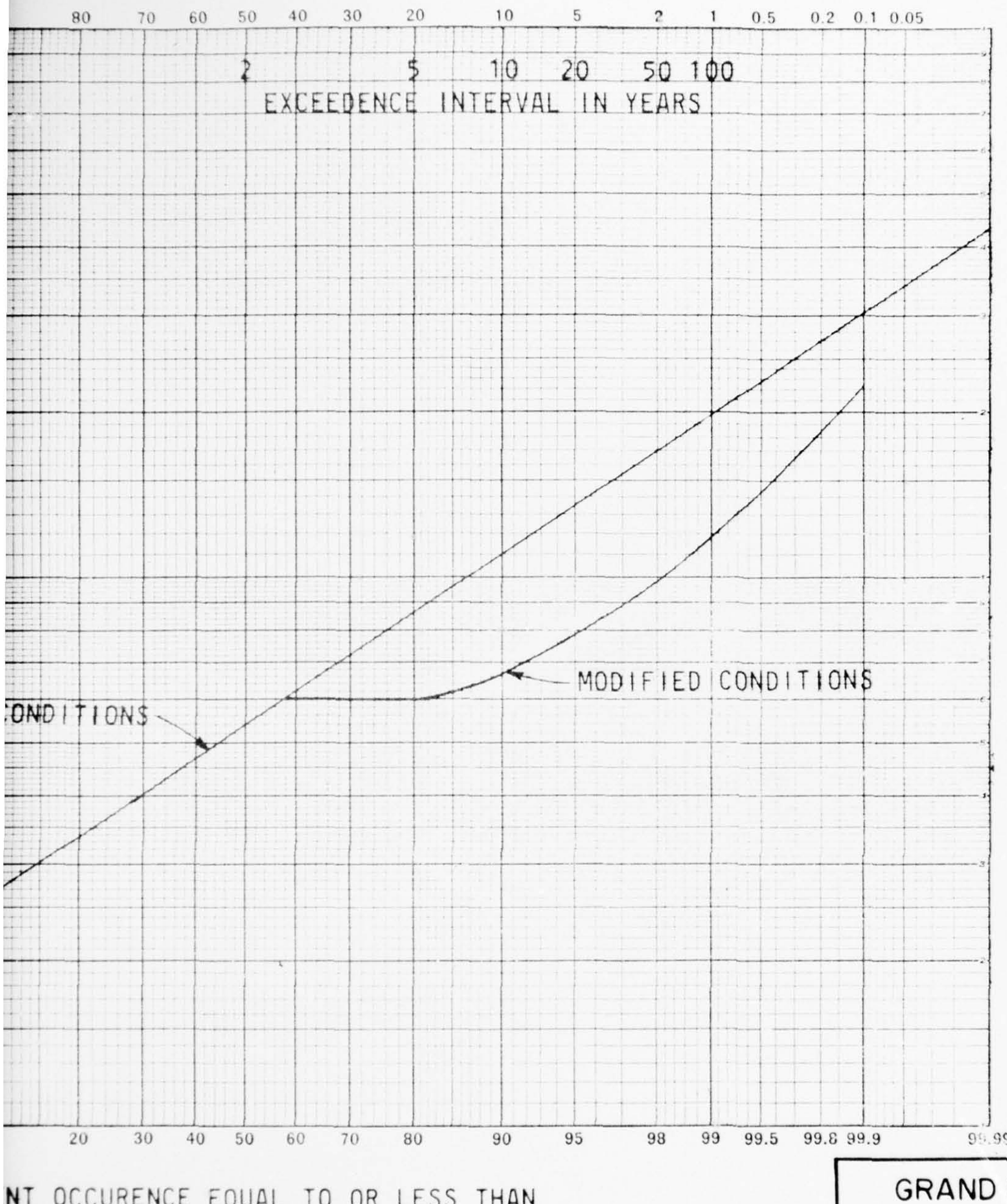


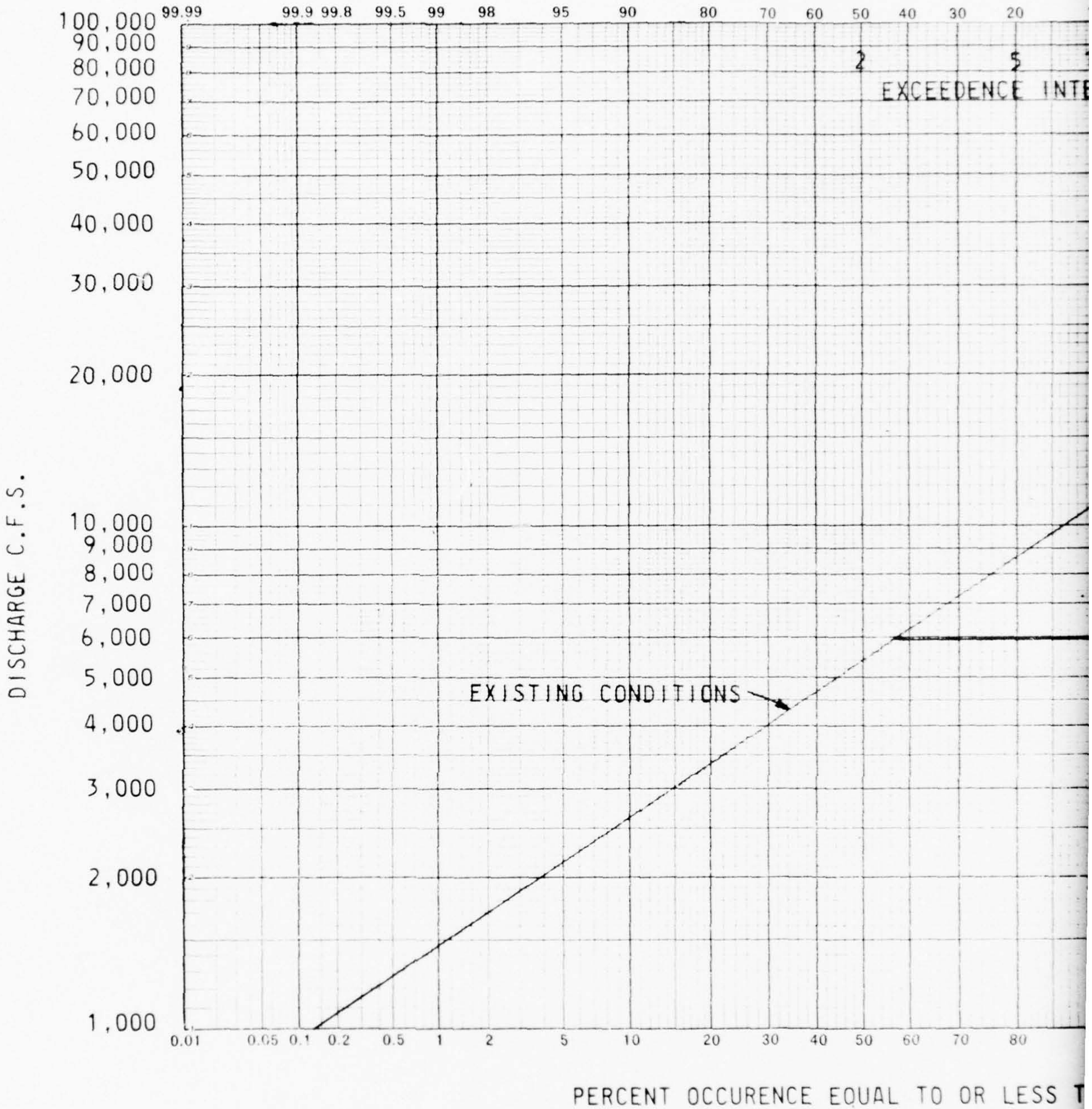
SITE NO.	SITE NAME	COND.	STORAGE
57	OKEMOS		23,800 ACRE FT.
62	TOMPKINS CENTER		7,452 ACRE FT.

GRAND RIVER BASIN, MICH.
PRELIMINARY RESERVOIR SCREENING
JANUARY 1966

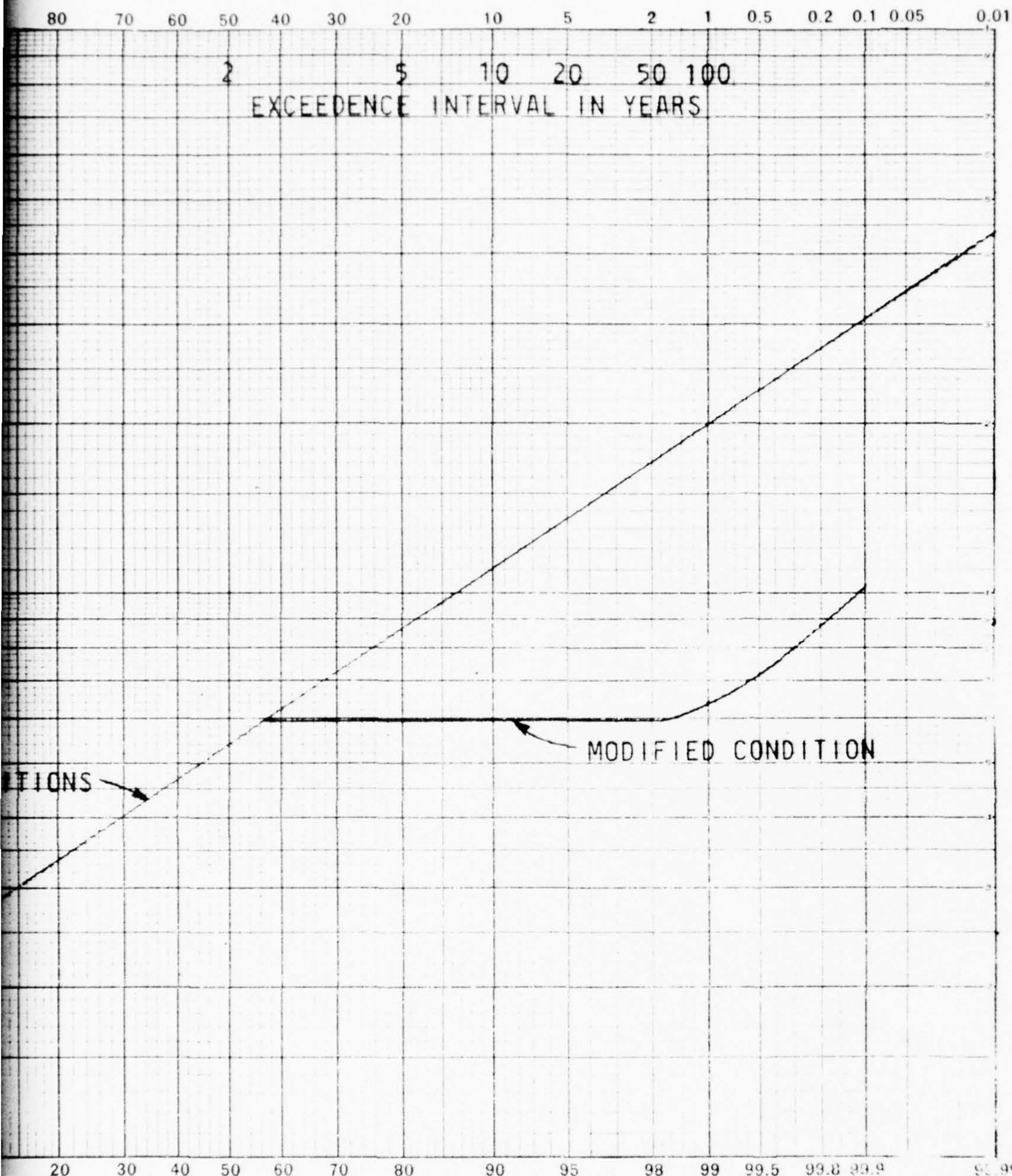
DISCHARGE FREQUENCY OF
GRAND RIVER AT LANSING

FIGURE H-16

U. S. ARMY



SITE NO.	SITE NA
5	MILLETT
58	WILLIAMST
62	TOMPKIN CENTER



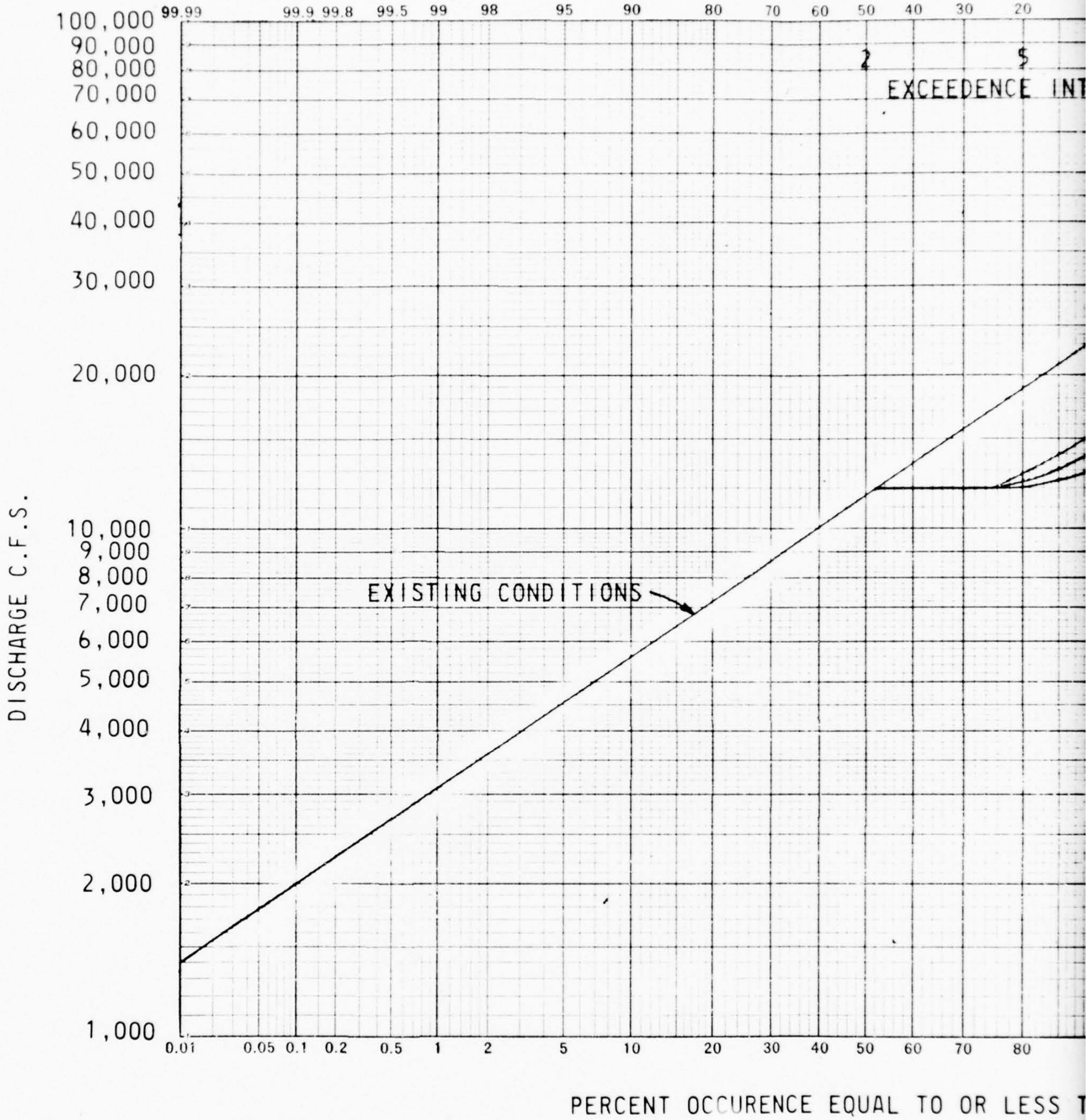
T OCCURENCE EQUAL TO OR LESS THAN

SITE NO.	SITE NAME	COND.	STORAGE
5	MILLETT		40,920 ACRE FT.
58	WILLIAMSTON		33,950 ACRE FT.
62	TOMPKINS CENTER		12,779 ACRE FT.

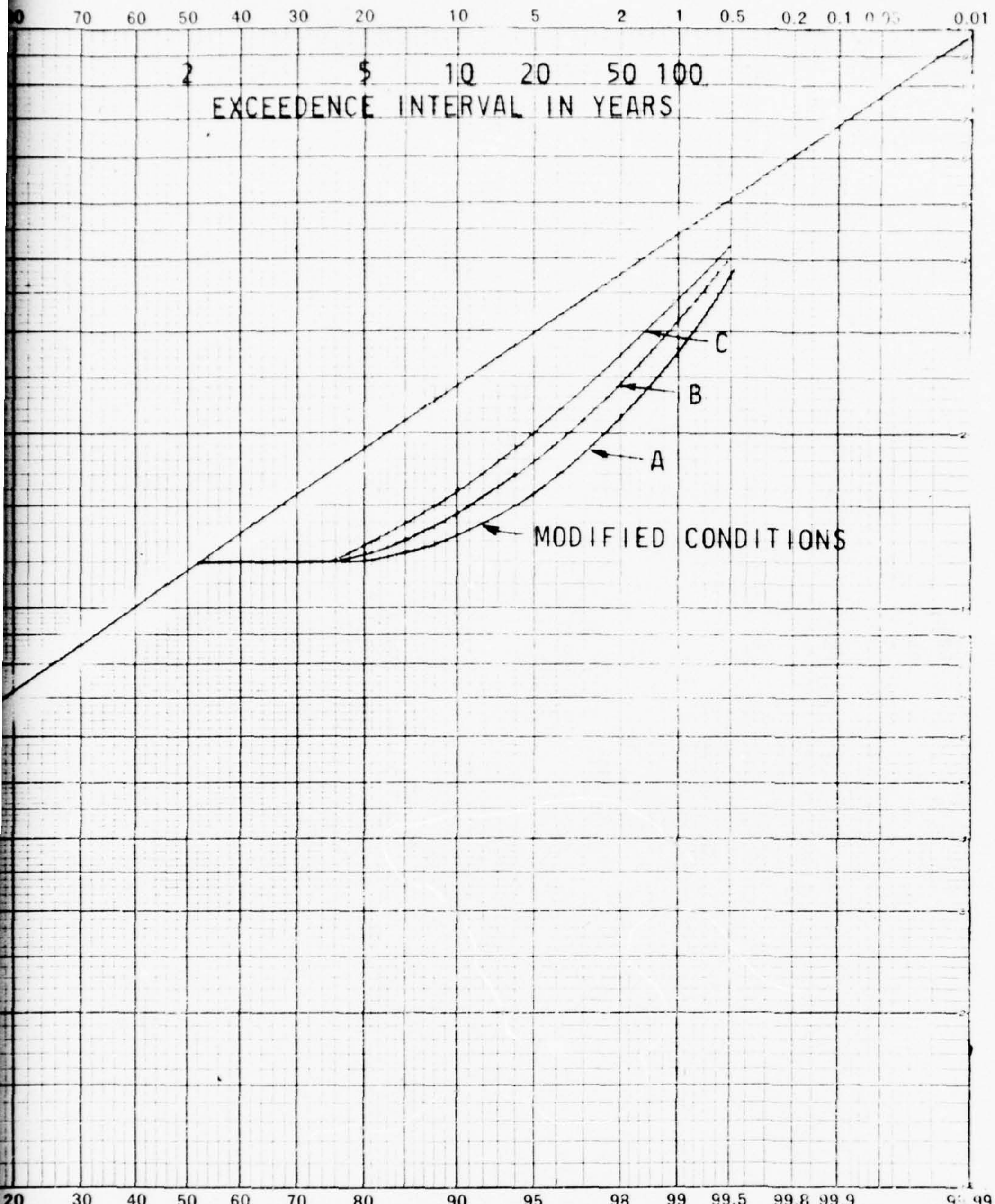
GRAND RIVER BASIN, MICH.
PRELIMINARY RESERVOIR SCREENING
JANUARY 1966

DISCHARGE FREQUENCY OF
GRAND RIVER AT LANSING

FIGURE H-17



SITE NO.	SITE NA
46	MUIR



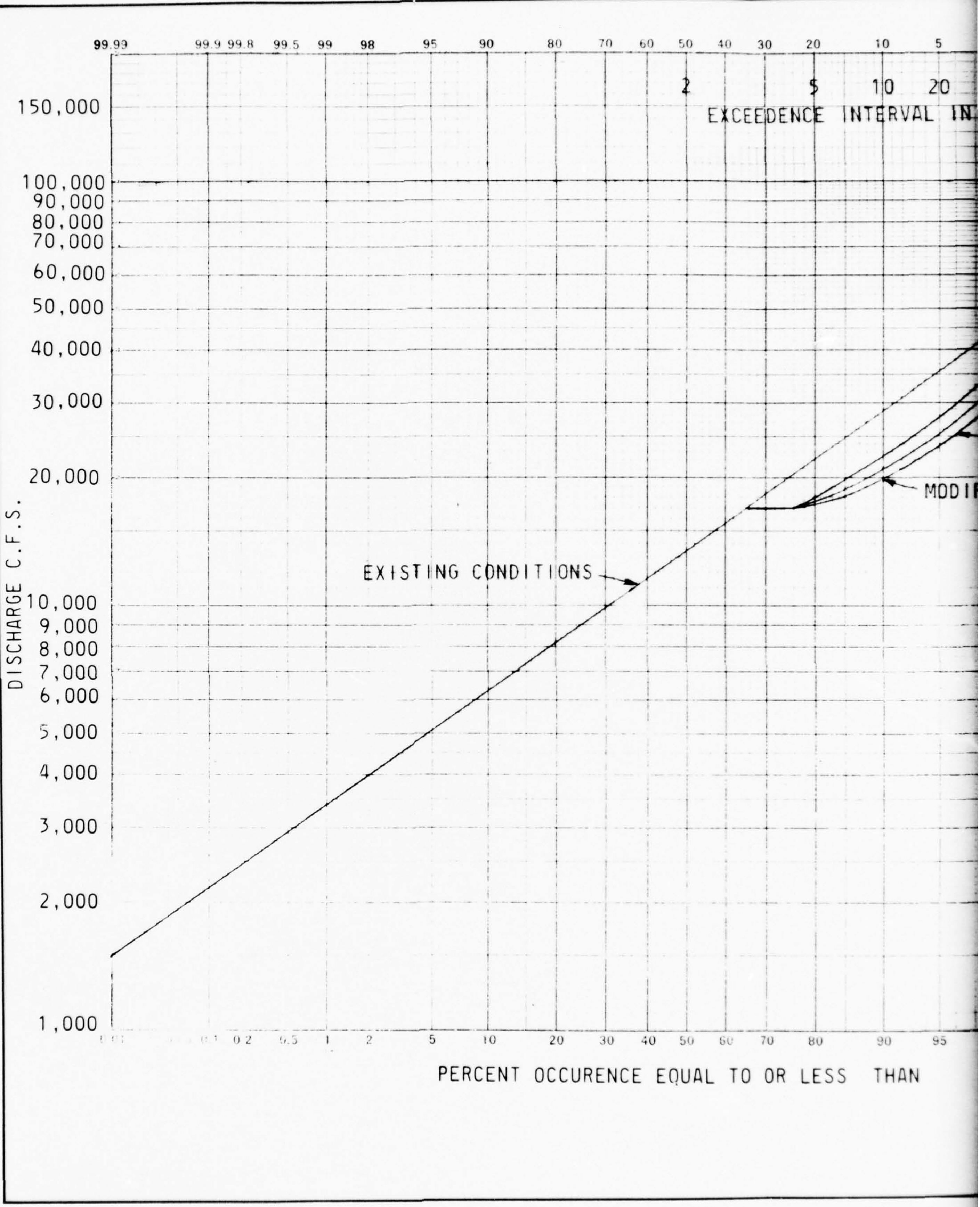
CCURENCE EQUAL TO OR LESS THAN

SITE NO.	SITE NAME	COND.	STORAGE
46	MUIR	A	89,800 ACRE FT.
		B	70,000 ACRE FT.
		C	50,000 ACRE FT.

GRAND RIVER BASIN, MICH.
PRELIMINARY RESERVOIR SCREENING
JANUARY 1966

DISCHARGE FREQUENCY OF
GRAND RIVER AT IONIA

FIGURE H-18



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PERCENT OCCURENCE EQUAL TO OR LESS THAN

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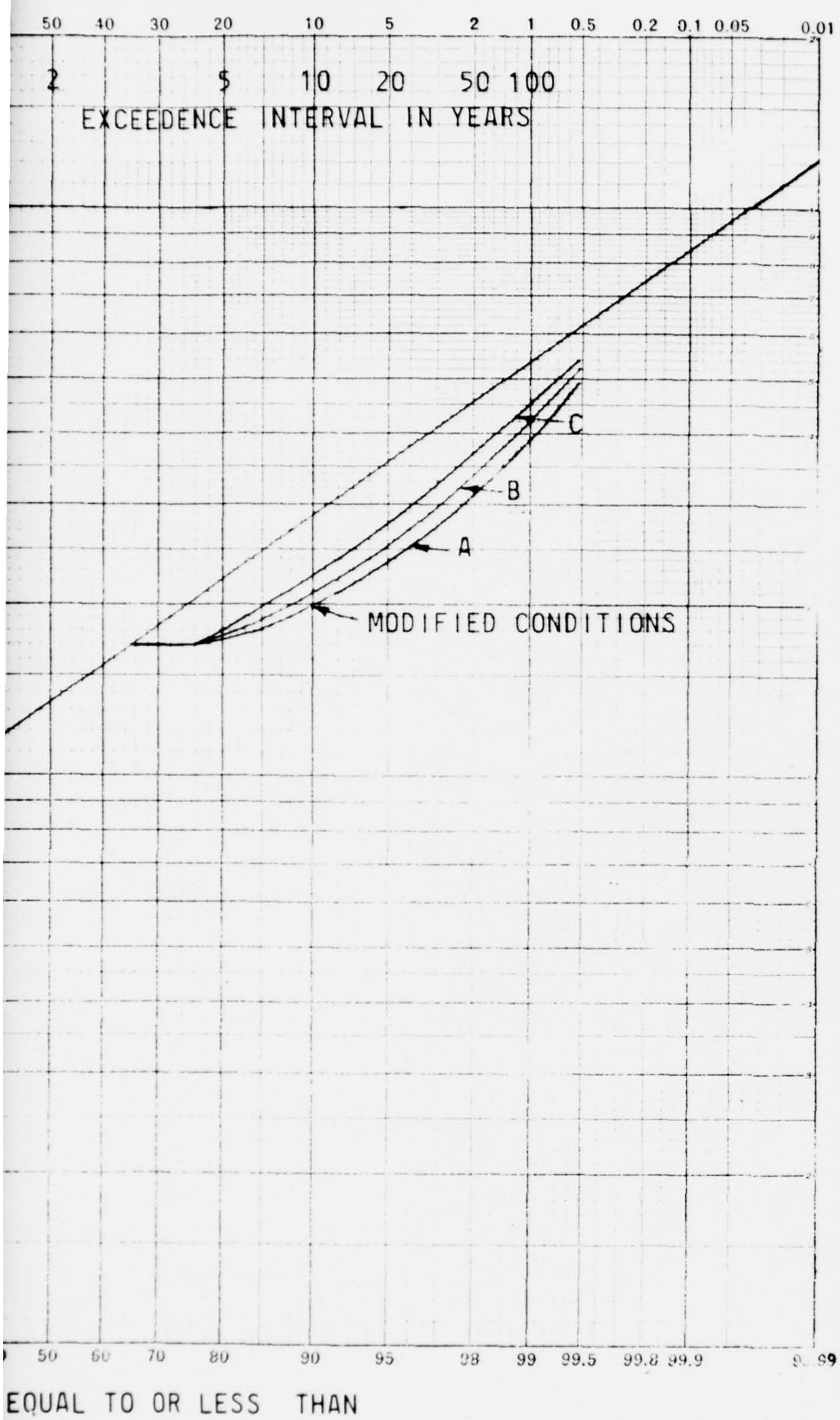
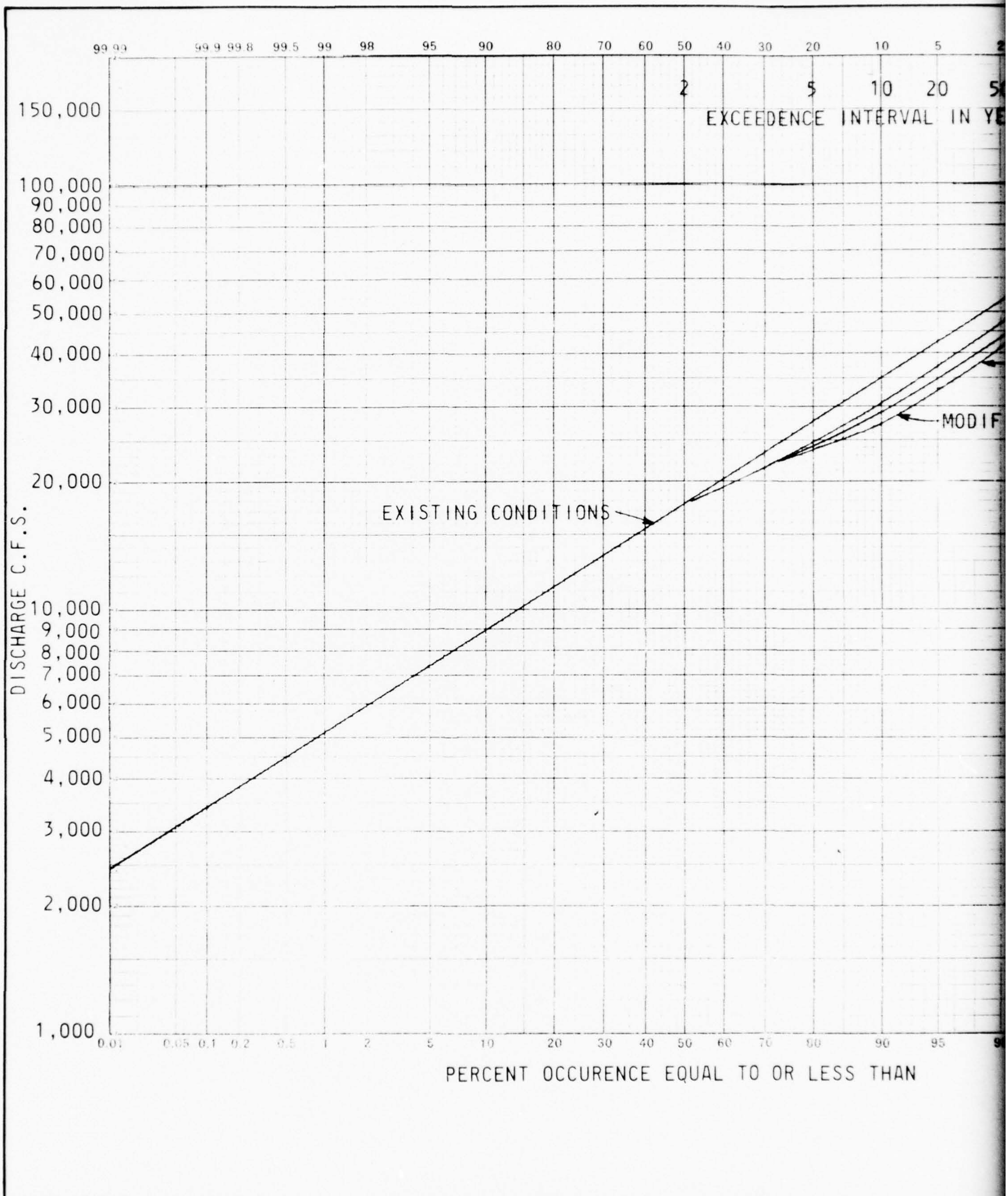


SITE NO.	SITE NO.	COND.	STORAGE
46	MUIR	A	89,800 ACRE FT.
		B	70,000 ACRE FT.
		C	50,000 ACRE FT.

GRAND RIVER BASIN, MICH.
PRELIMINARY RESERVOIR SCREENING
JANUARY 1966

DISCHARGE FREQUENCY OF
GRAND RIVER AT LOWELL

FIGURE H-19


EXCEEDENCE INTERVAL IN YE
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DISCHARGE C.F.S.
EXISTING CONDITIONS
MODIF
PERCENT OCCURENCE EQUAL TO OR LESS THAN

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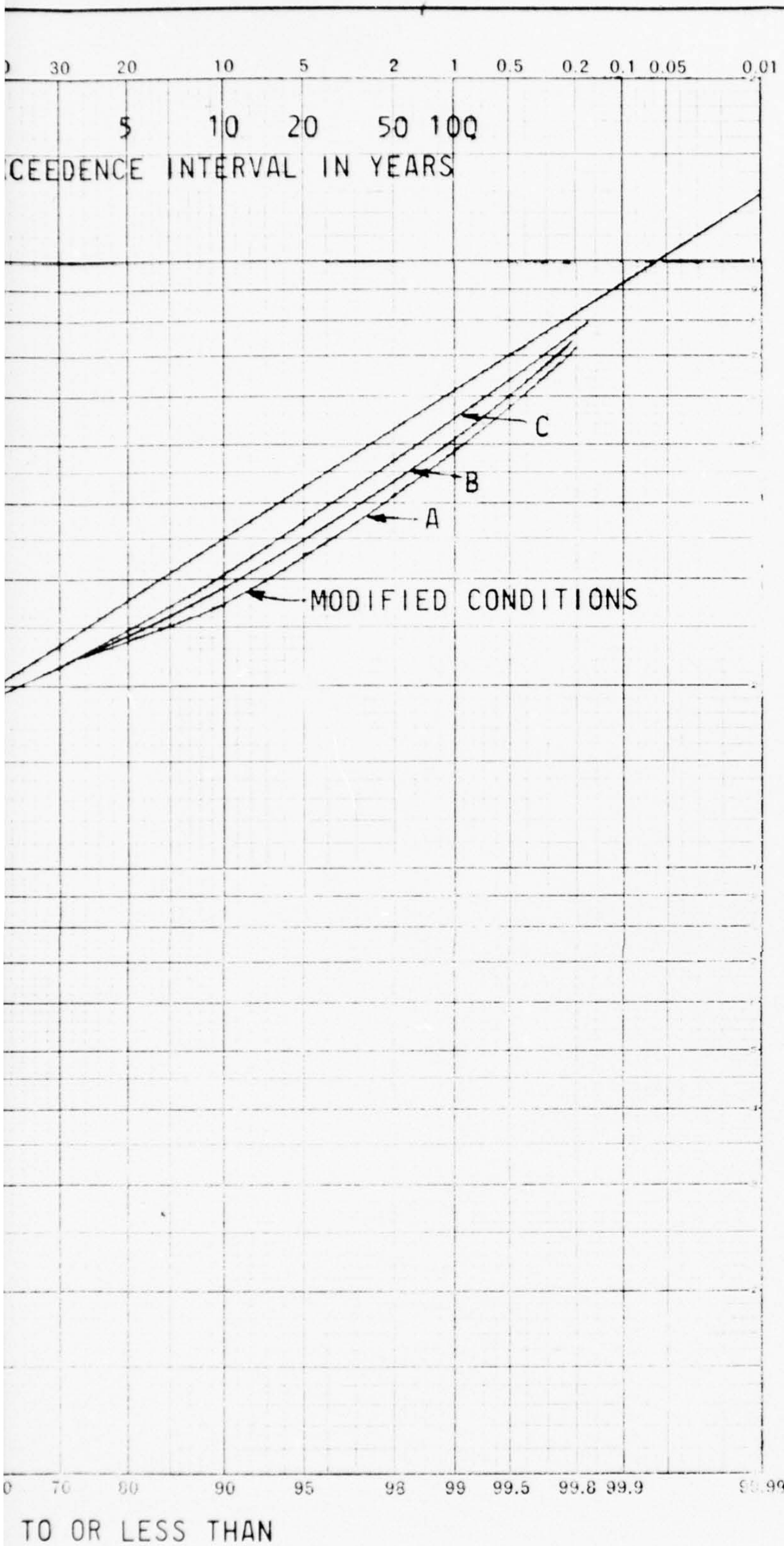


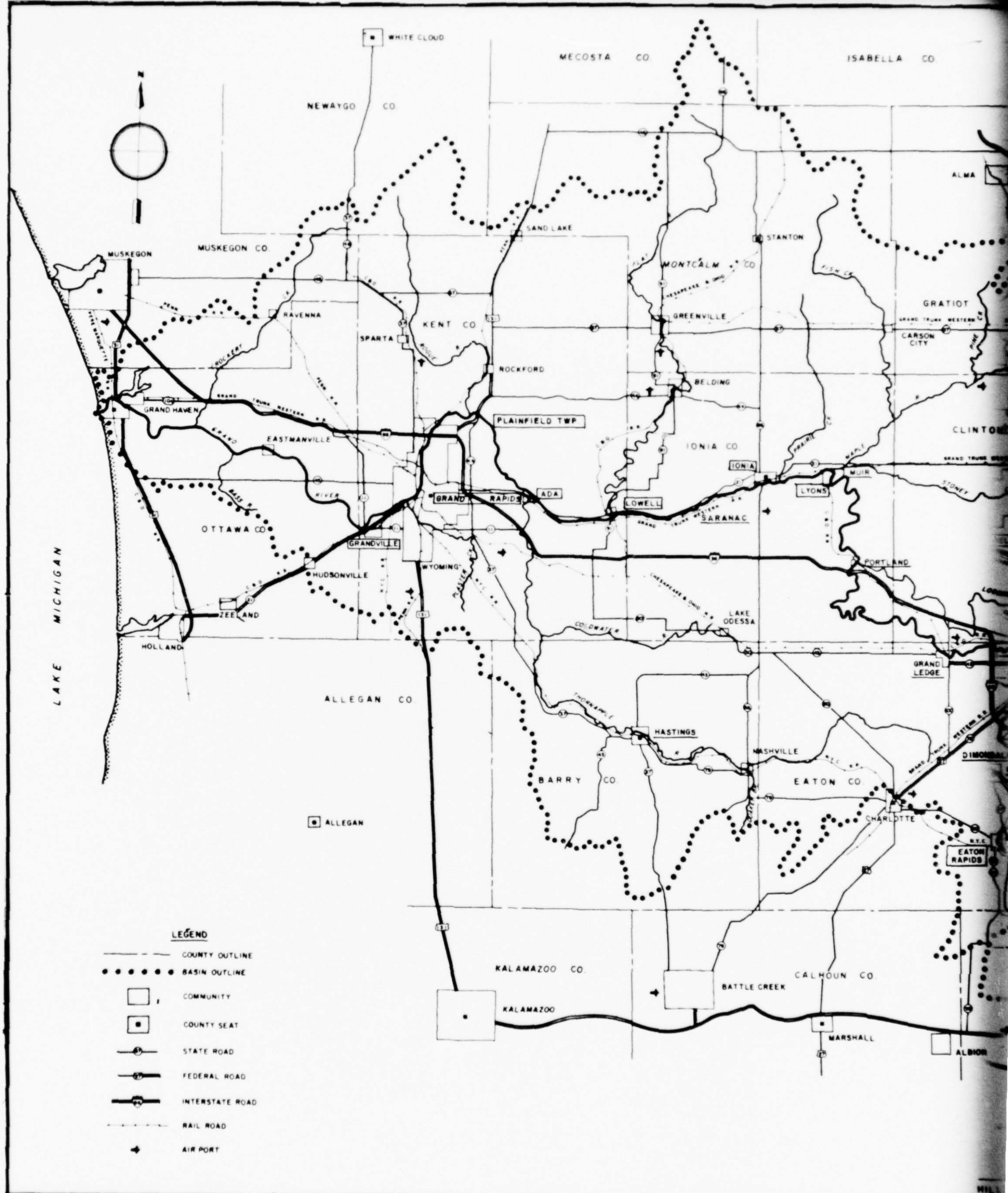
SITE NO.	SITE NAME	COND.	STORAGE
46	MUIR	A	89,800 ACRE FT.
		B	70,000 ACRE FT.
		C	50,000 ACRE FT.

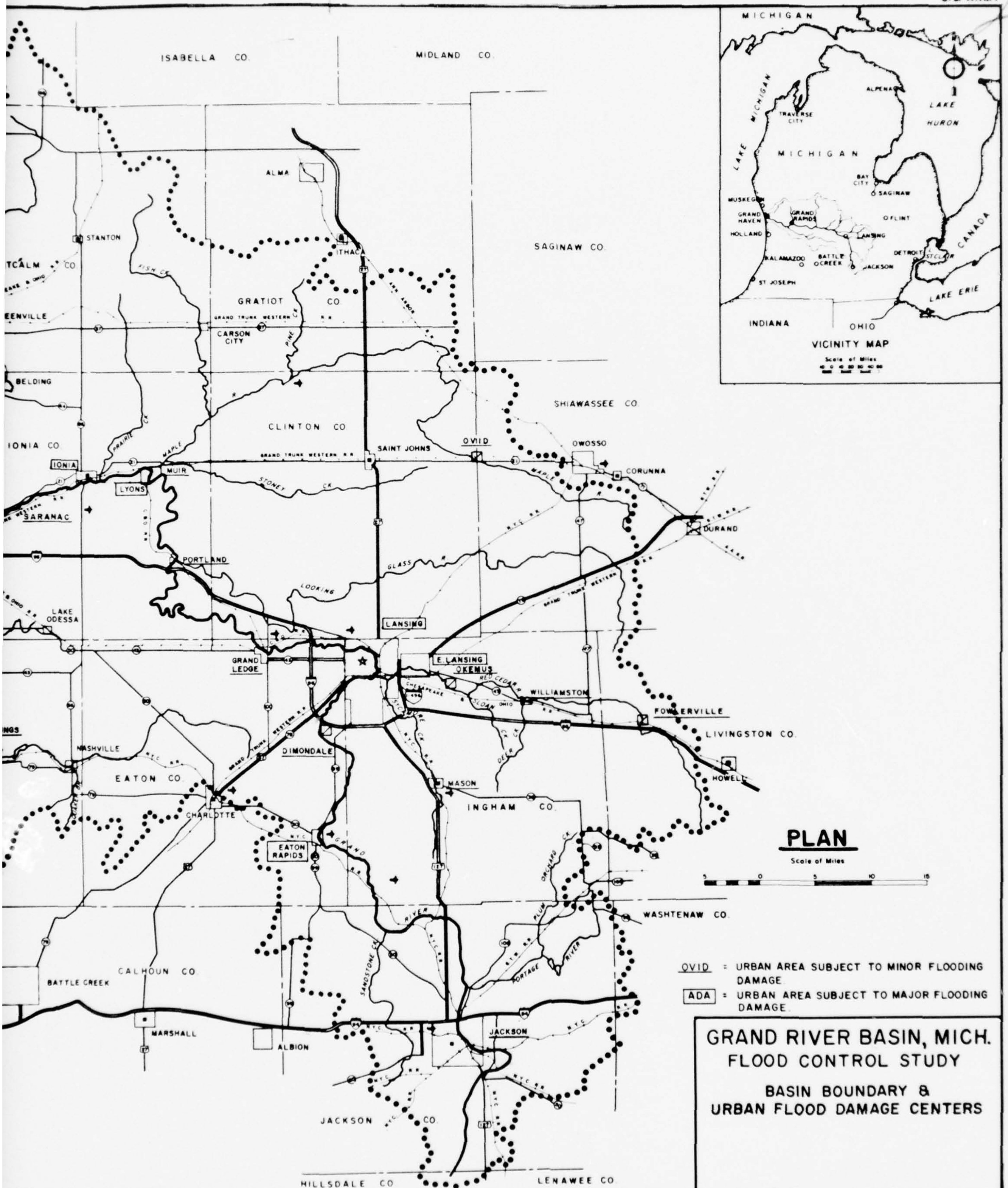
GRAND RIVER BASIN, MICH.
PRELIMINARY RESERVOIR SCREENING
JANUARY 1966

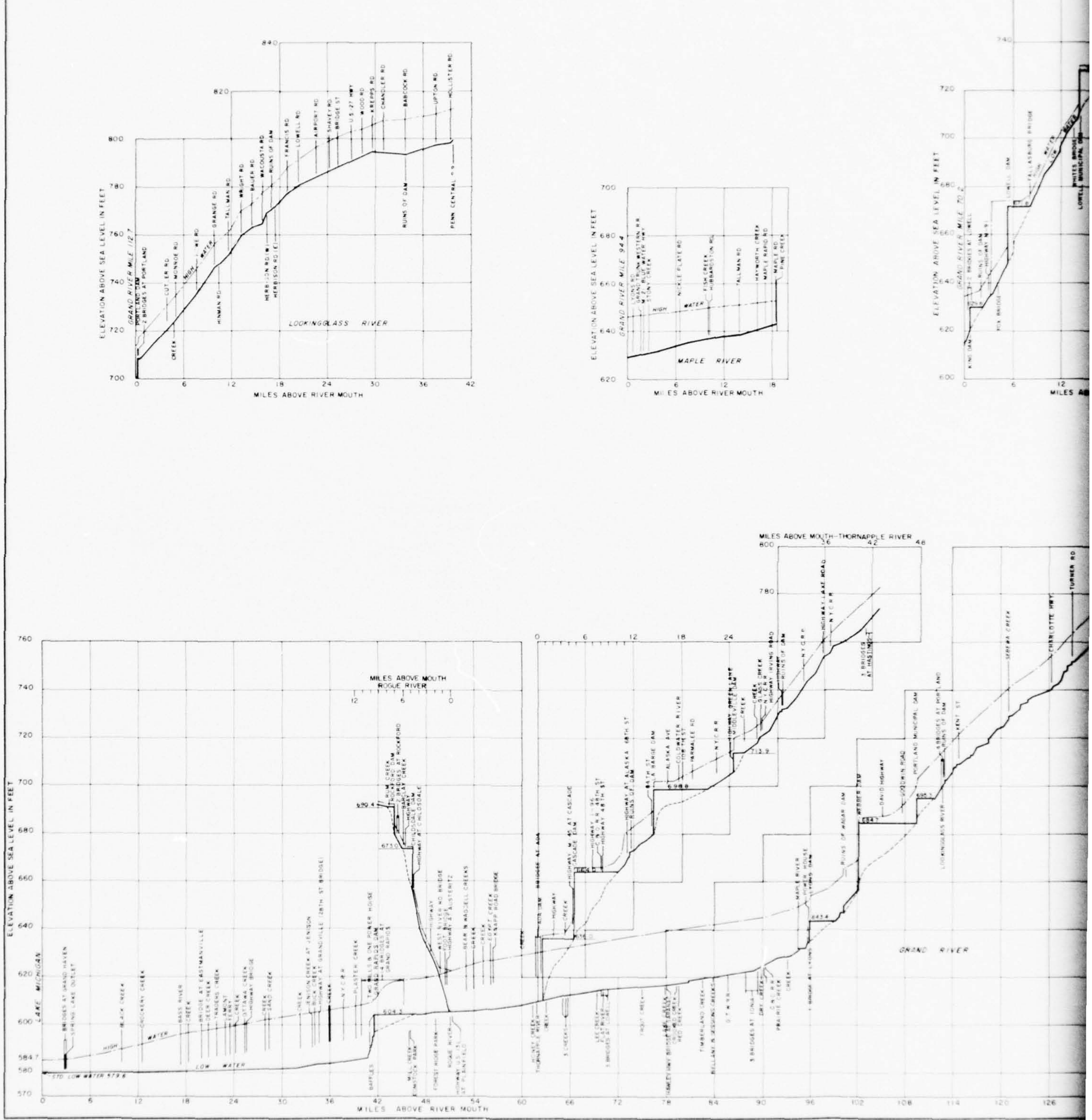
DISCHARGE FREQUENCY OF
GRAND RIVER AT GRAND RAPIDS

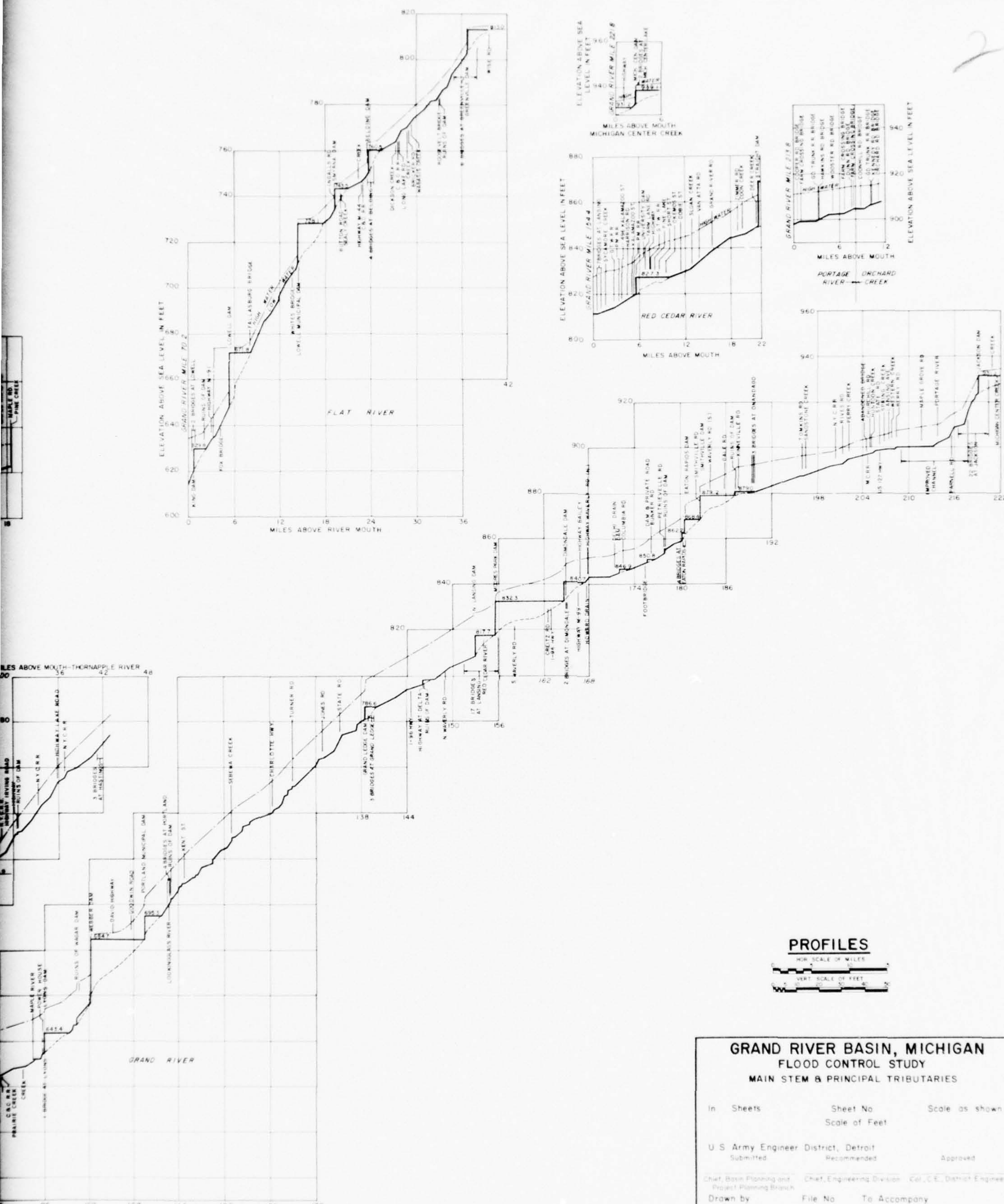
FIGURE H-20

CORPS OF ENGINEERS




GRAND RIVER BASIN, MICH.
FLOOD CONTROL STUDY
BASIN BOUNDARY & URBAN FLOOD DAMAGE CENTERS
PLAN
Scale of Miles
OVID = URBAN AREA SUBJECT TO MINOR FLOODING DAMAGE.
ADA = URBAN AREA SUBJECT TO MAJOR FLOODING DAMAGE.
VICINITY MAP
MICHIGAN
LAKE MICHIGAN
LAKE HURON
LAKE ERIE
CANADA
INDIANA
OHIO
TRAVERSE CITY
ALPENA
BAY CITY
SAGINAW
MUSKEGON
GRAND HAVEN
GRAND RAPIDS
HOLLAND
FLINT
LANSING
KALAMAZOO
BATTLE CREEK
JACKSON
DETROIT
ST. JOSEPH
ISABELLA CO.
MIDLAND CO.
SAGINAW CO.
GRATIOT CO.
SHIAWASSEE CO.
CLINTON CO.
IONIA CO.
EATON CO.
INGHAM CO.
LIVINGSTON CO.
WASHTENAW CO.
CALHOUN CO.
JACKSON CO.
HILLSDALE CO.
LENAWEE CO.
ALMA
STANTON
ITHACA
CARSON CITY
BELDING
IONIA
LYONS
MUIR
SARANAC
SAINT JOHNS
OVID
OWOSSO
CORUNNA
DURAND
PORTLAND
LAKE ODESSA
LANSING
GRAND LEDGE
E. LANSING
OKEMUS
WILLIAMSTON
FOWLERVILLE
HOWELL
NASHVILLE
DIMONDALE
CHARLOTTE
MASON
EATON RAPIDS
BATTLE CREEK
MARSHALL
ALBION
JACKSON
GRAND TRUNK WESTERN R.R.
MAPLE R.
STONEY CR.
LOOKING GLASS R.
RED CEDAR R.
SLOAN CR.
DEER CR.
GRAND R.
GRAND RIVER
SANDSTONE CR.
PORTAGE RIVER
ORCHARD CR.
PRAIRIE CR.
FISH CR.
PINE CR.


ELEVATION ABOVE SEA LEVEL IN FEET
MILES ABOVE RIVER MOUTH
GRAND RIVER MILE 112.7
LOOKINGGLASS RIVER
GRAND RIVER MILE 94.4
MAPLE RIVER
GRAND RIVER MILE 70.2
MILES ABOVE MOUTH-THORNAPPLE RIVER
MILES ABOVE MOUTH
ROGUE RIVER
LAKE MICHIGAN
HIGH WATER
LOW WATER
STD LOW WATER 579.6
GRAND RIVER



GRAND RIVER BASIN, MICHIGAN

FLOOD CONTROL STUDY

MAIN STEM & PRINCIPAL TRIBUTARIES

In Sheets	Sheet No.	Scale as shown
	Scale of Feet	

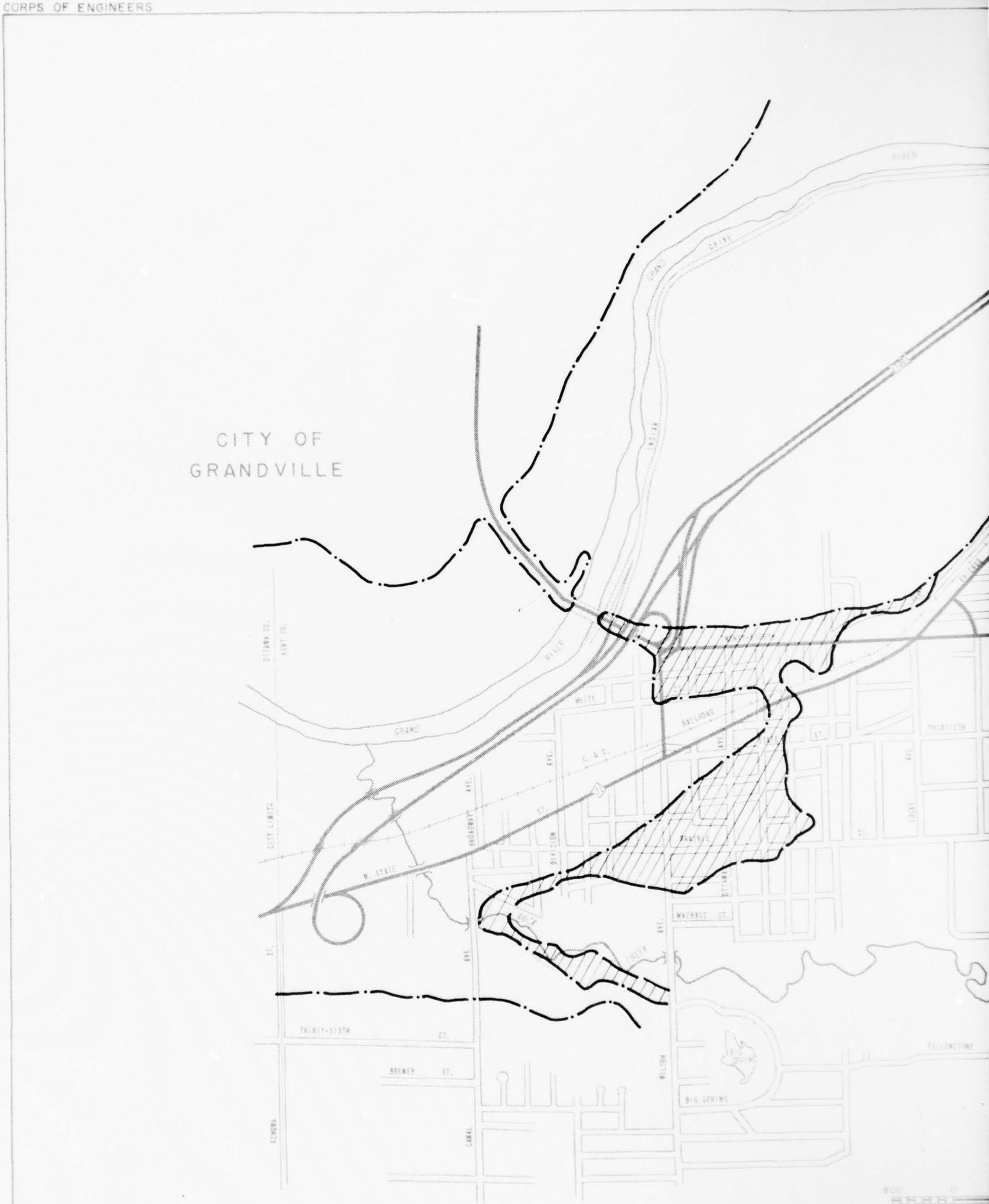
U. S. Army Engineer District, Detroit

Submitted	Recommended	Approved
Chief, Basin Planning and Project Planning Branch	Chief, Engineering Division	Col., C.E., District Engineer

Drawn by File No. To Accompany

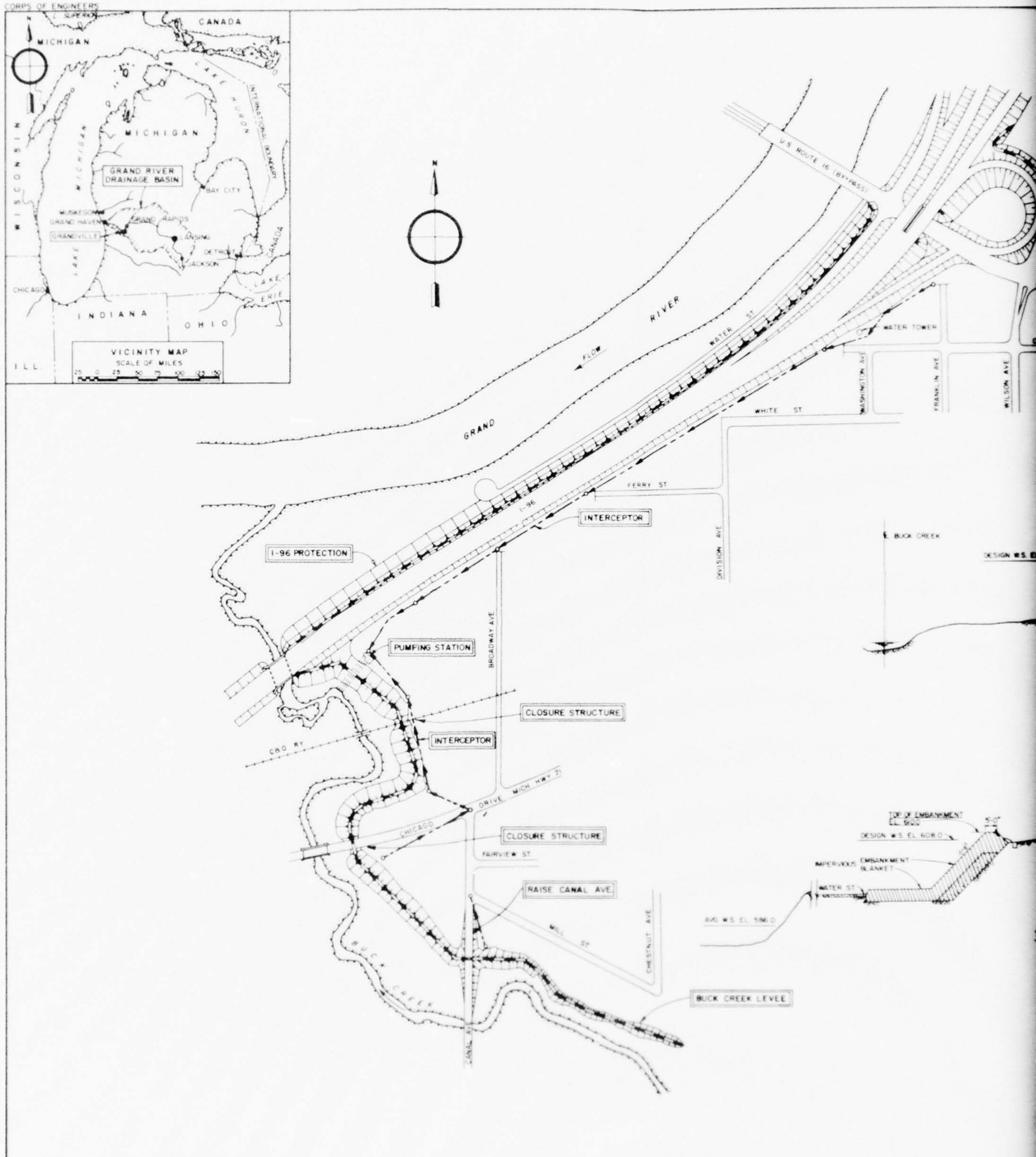
Checked by

CORPS OF ENGINEERS



U. S. ARMY

PLATE H-3



CORPS OF ENGINEERS
L. SUPERIOR
CANADA
MICHIGAN
LAKE HURON
INTERNATIONAL BOUNDARY
WISCONSIN
LAKE MICHIGAN
MICHIGAN
GRAND RIVER
DRAINAGE BASIN
BAY CITY
MUSKEGON
GRAND HAVEN
GRAND RAPIDS
GRANDVILLE
LANSING
DETROIT
JACKSON
CANADA
CHICAGO
LAKE ERIE
INDIANA
OHIO
ILL.
VICINITY MAP
SCALE OF MILES
U.S. ROUTE 16 (BY-PASS)
GRAND RIVER
FLOW
WATER ST.
WATER TOWER
WASHINGTON AVE
FRANKLIN AVE
WILSON AVE
WHITE ST.
FERRY ST.
I-96
INTERCEPTOR
DIVISION AVE
I-96 PROTECTION
BUCK CREEK
DESIGN W.S. EL
PUMPING STATION
BROADWAY AVE
CLOSURE STRUCTURE
C&O RY
INTERCEPTOR
CHICAGO DRIVE MICH HWY 21
CLOSURE STRUCTURE
FAIRVIEW ST.
RAISE CANAL AVE.
MILL ST.
CHESTNUT AVE
BUCK CREEK
CANAL AVE
BUCK CREEK LEVEE
TOP OF EMBANKMENT
DESIGN W.S. EL 608.0
IMPERVIOUS BLANKET
EMBANKMENT
WATER ST.
AVG W.S. EL 586.0

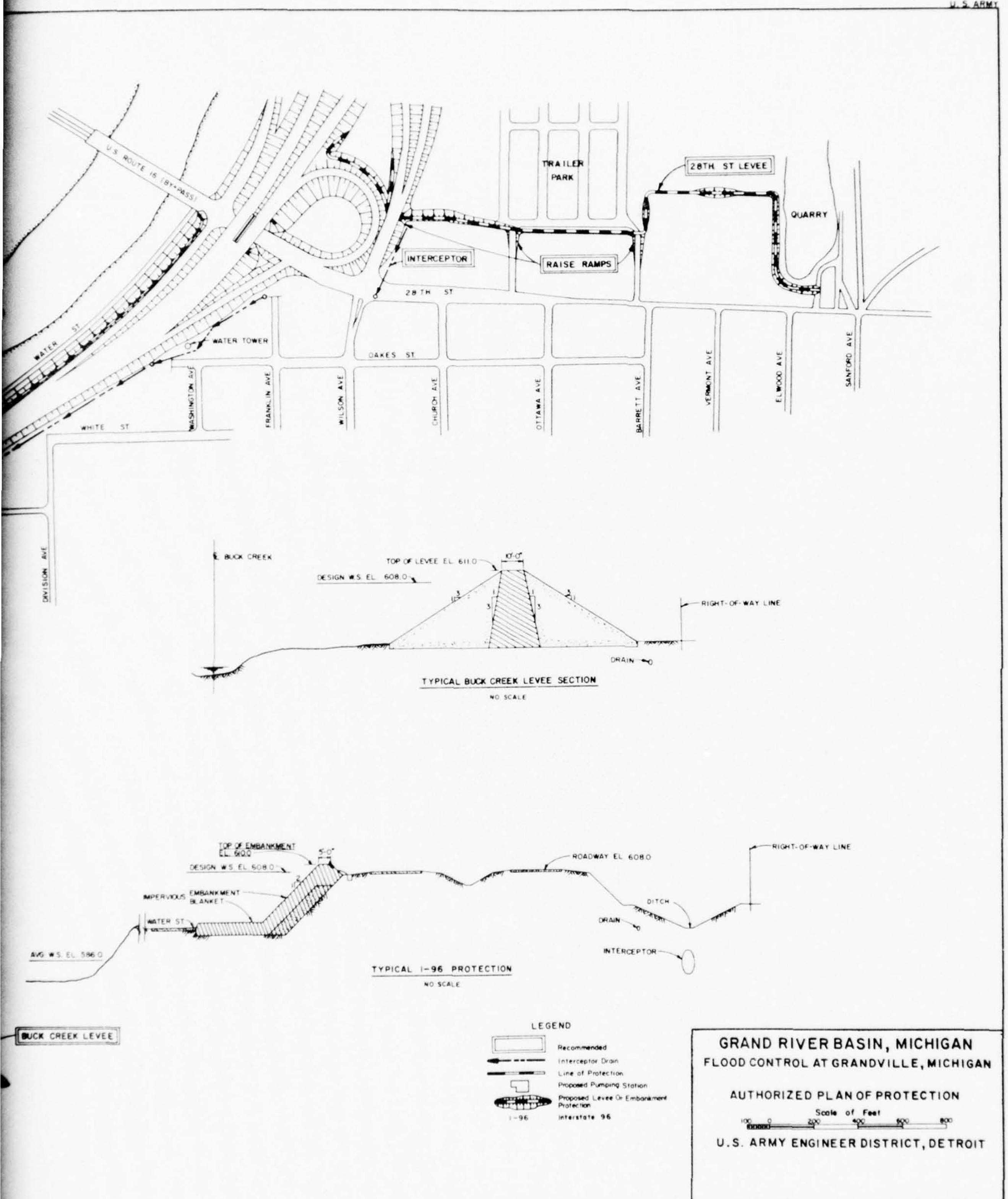
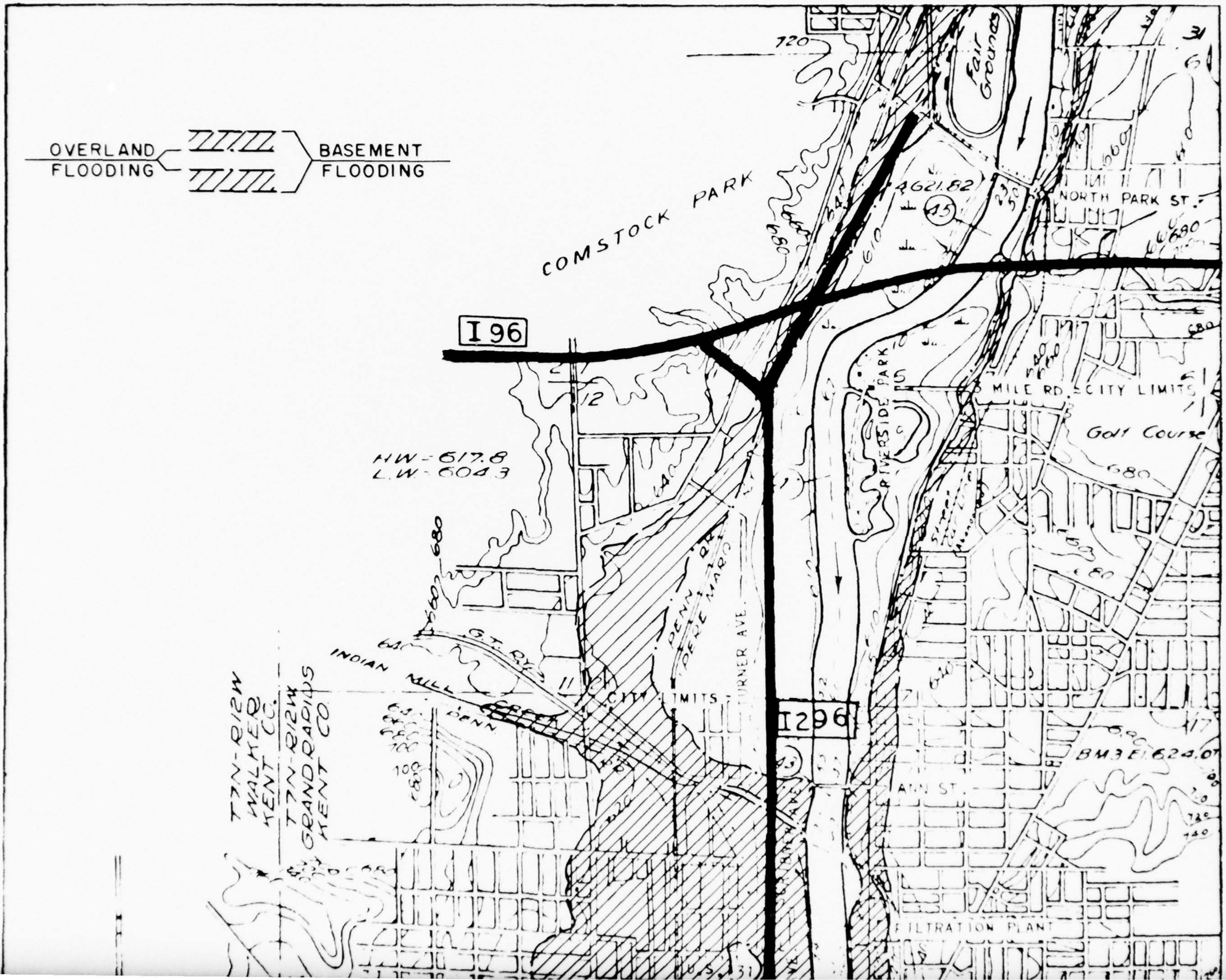
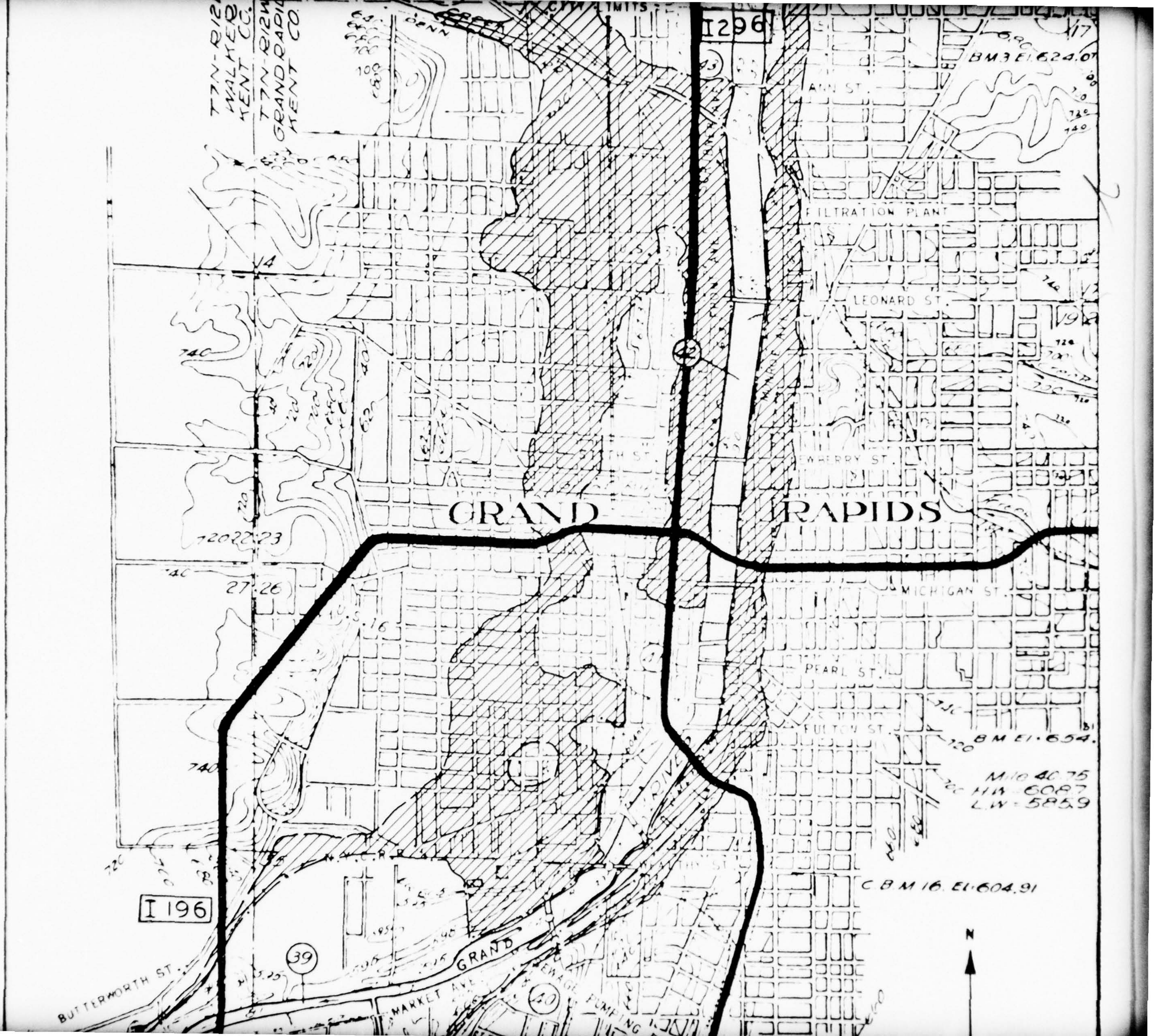

U. S. ARMY
U.S. ROUTE 16 (BY-PASS)
TRAILER PARK
28TH. ST LEVEE
QUARRY
INTERCEPTOR
RAISE RAMPS
28TH ST
WATER ST
WATER TOWER
OAKES ST
WASHINGTON AVE
FRANKLIN AVE
WILSON AVE
CHURCH AVE
OTTAWA AVE
BARRETT AVE
VERMONT AVE
ELWOOD AVE
SANFORD AVE
WHITE ST
DIVISION AVE
℄ BUCK CREEK
TOP OF LEVEE EL. 611.0
10'-0"
DESIGN W.S. EL. 608.0
RIGHT-OF-WAY LINE
DRAIN
TYPICAL BUCK CREEK LEVEE SECTION
NO SCALE
TOP OF EMBANKMENT EL. 610.0
5'-0"
DESIGN W.S. EL. 608.0
ROADWAY EL. 608.0
RIGHT-OF-WAY LINE
IMPERVIOUS BLANKET
EMBANKMENT
WATER ST
AVG W.S. EL. 586.0
DITCH
DRAIN
INTERCEPTOR
TYPICAL I-96 PROTECTION
NO SCALE
BUCK CREEK LEVEE
LEGEND
Recommended
Interceptor Drain
Line of Protection
Proposed Pumping Station
Proposed Levee Or Embankment Protection
I-96
Interstate 96
GRAND RIVER BASIN, MICHIGAN
FLOOD CONTROL AT GRANDVILLE, MICHIGAN
AUTHORIZED PLAN OF PROTECTION
Scale of Feet
100 0 200 400 600 800
U.S. ARMY ENGINEER DISTRICT, DETROIT

PLATE H-4


OVERLAND FLOODING
BASEMENT FLOODING
COMSTOCK PARK
I 96
I 296
Fair Grounds
NORTH PARK ST.
RIVERSIDE PARK
MILE RD. CITY LIMITS
Golf Course
HW - 617.8
L.W. - 604.3
G.T. RYS
INDIAN MILL CREEK
PENN
PERE MARQ
TURNER AVE.
CITY LIMITS
ANN ST.
BM3 El. 624.07
FILTRATION PLANT
T7N-R12W
WALKER
KENT CO.
T7N-R12W
GRAND RAPIDS
KENT CO
462.82
720
680
660
640
610


GRAND RAPIDS
I 296
I 196
FILTRATION PLANT
LEONARD ST.
MICHIGAN ST.
PEARL ST.
FULTON ST.
BUTTERWORTH ST.
MARKET AVE.
GRAND
RIVER
T7N-R12W
WALKER
KENT CO.
T7N-R12W
GRAND RAPIDS
KENT CO
BM 3 El. 624.07
BM El. 654.
Mile 40.75
H.W. 608.7
L.W. 585.9
C.B.M 16. El. 604.91
39
40
42
N

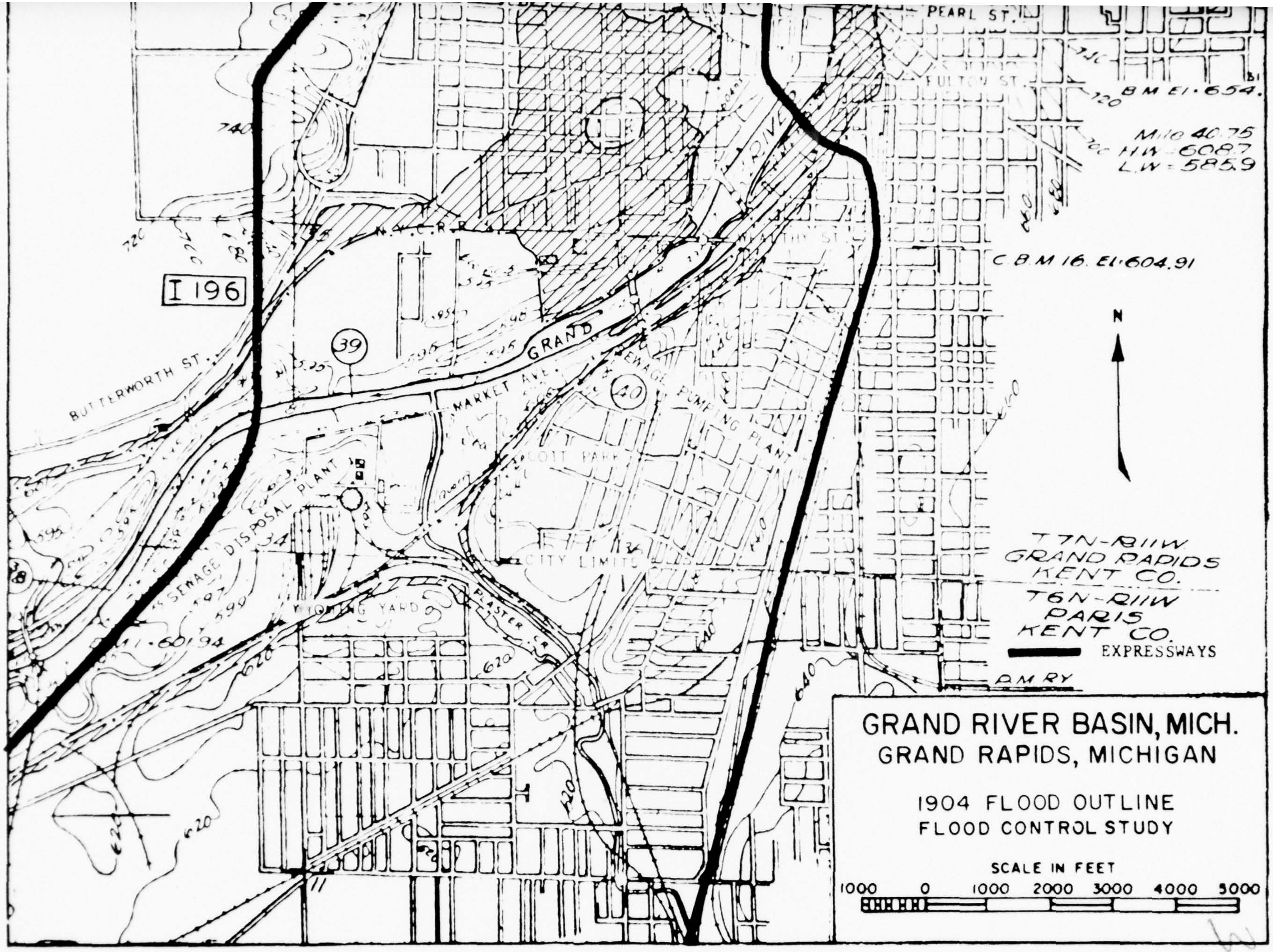
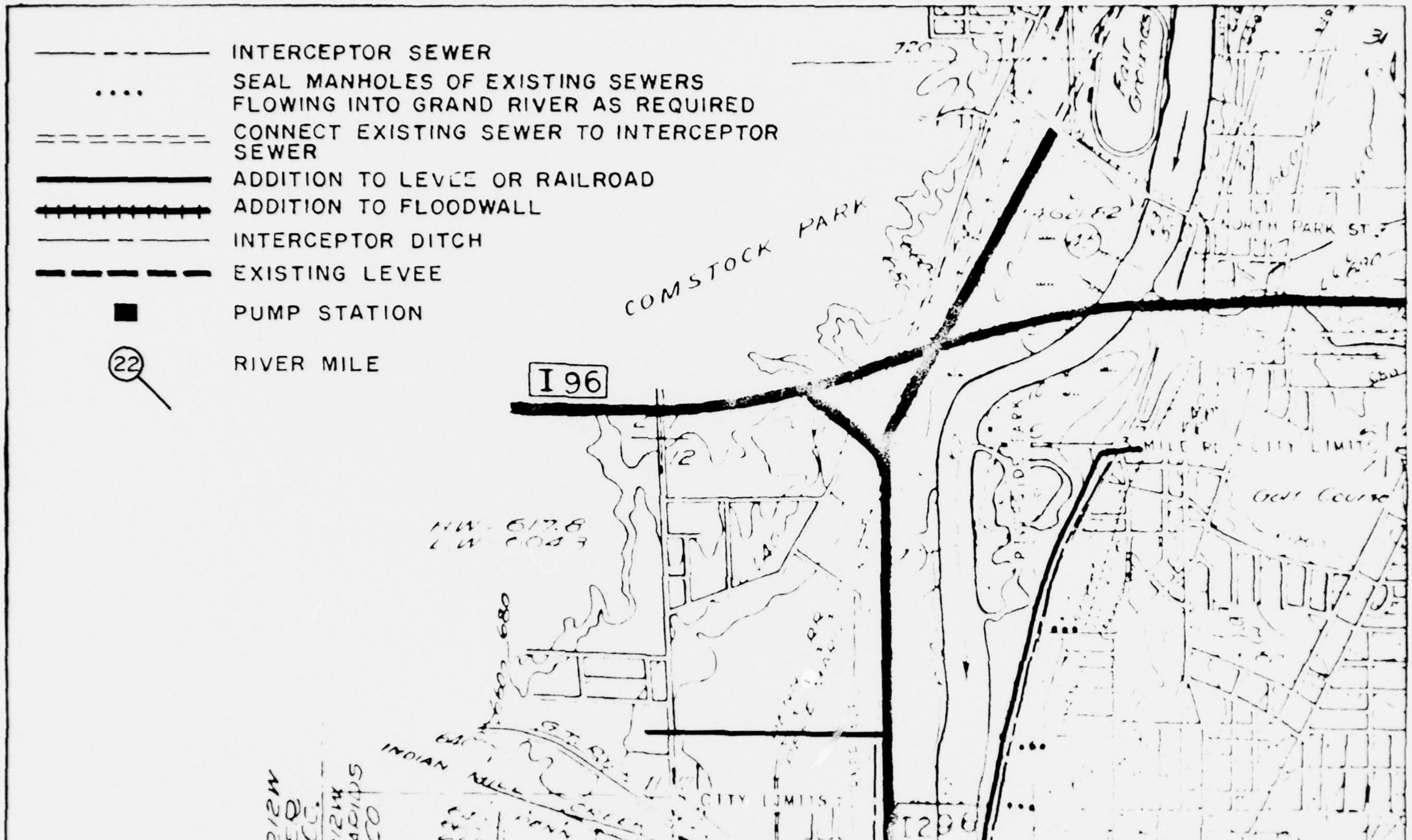

GRAND RIVER BASIN, MICH.
GRAND RAPIDS, MICHIGAN
1904 FLOOD OUTLINE
FLOOD CONTROL STUDY
SCALE IN FEET
1000 0 1000 2000 3000 4000 5000
EXPRESSWAYS
T7N-R11W
GRAND RAPIDS
KENT CO.
T6N-R11W
PARIS
KENT CO.
N
PEARL ST.
FULTON ST.
B M El. 654.
Mile 40.75
H.W. = 608.7
L.W. = 585.9
C.B.M 16. El. 604.91
I 196
39
40
GRAND
MARKET AVE.
BUTTERWORTH ST.
SEWAGE PUMPING PLANT
SEWAGE DISPOSAL PLANT
CITY LIMITS
PLASTER CR.
N.Y.C.R.R.
740
720
620
640

PLATE H-5


INTERCEPTOR SEWER
SEAL MANHOLES OF EXISTING SEWERS FLOWING INTO GRAND RIVER AS REQUIRED
CONNECT EXISTING SEWER TO INTERCEPTOR SEWER
ADDITION TO LEVEE OR RAILROAD
ADDITION TO FLOODWALL
INTERCEPTOR DITCH
EXISTING LEVEE
PUMP STATION
22
RIVER MILE
COMSTOCK PARK
I 96
Fair Grounds
NORTH PARK ST.
CITY LIMITS
Golf Course
CITY LIMITS
INDIAN MILL CREEK
G.T. RY.
T7N-R12W
WALKER
KENT CO.
T7N-R12W
GRAND RAPIDS
KENT CO
FILTRATION PLANT


GRAND RAPIDS
REMOVE DAM
NEW BRIDGES
RAISE BRIDGES
I 196
42
39
40
MICHIGAN ST.
PEARL ST.
FULTON ST.
LEONARD ST.
WEALTHY ST.
BUTTERWORTH ST.
MARKET AVE.
GRAND
SEWAGE PUMPING PLANT
FILTRATION PLANT
N.Y.C.R.R.
B.M. El. 654.
C.B.M. 16. El. 604.91
N

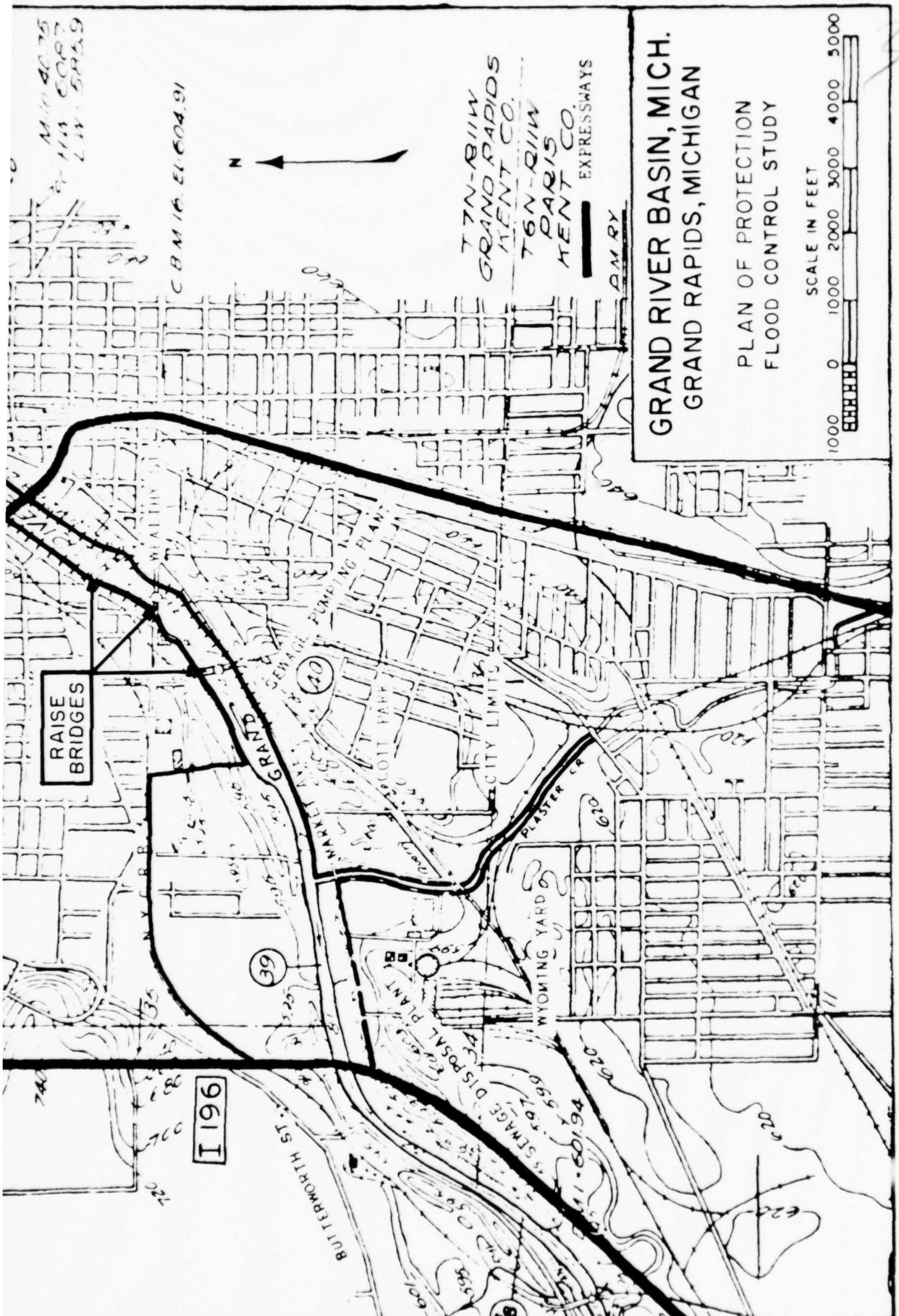
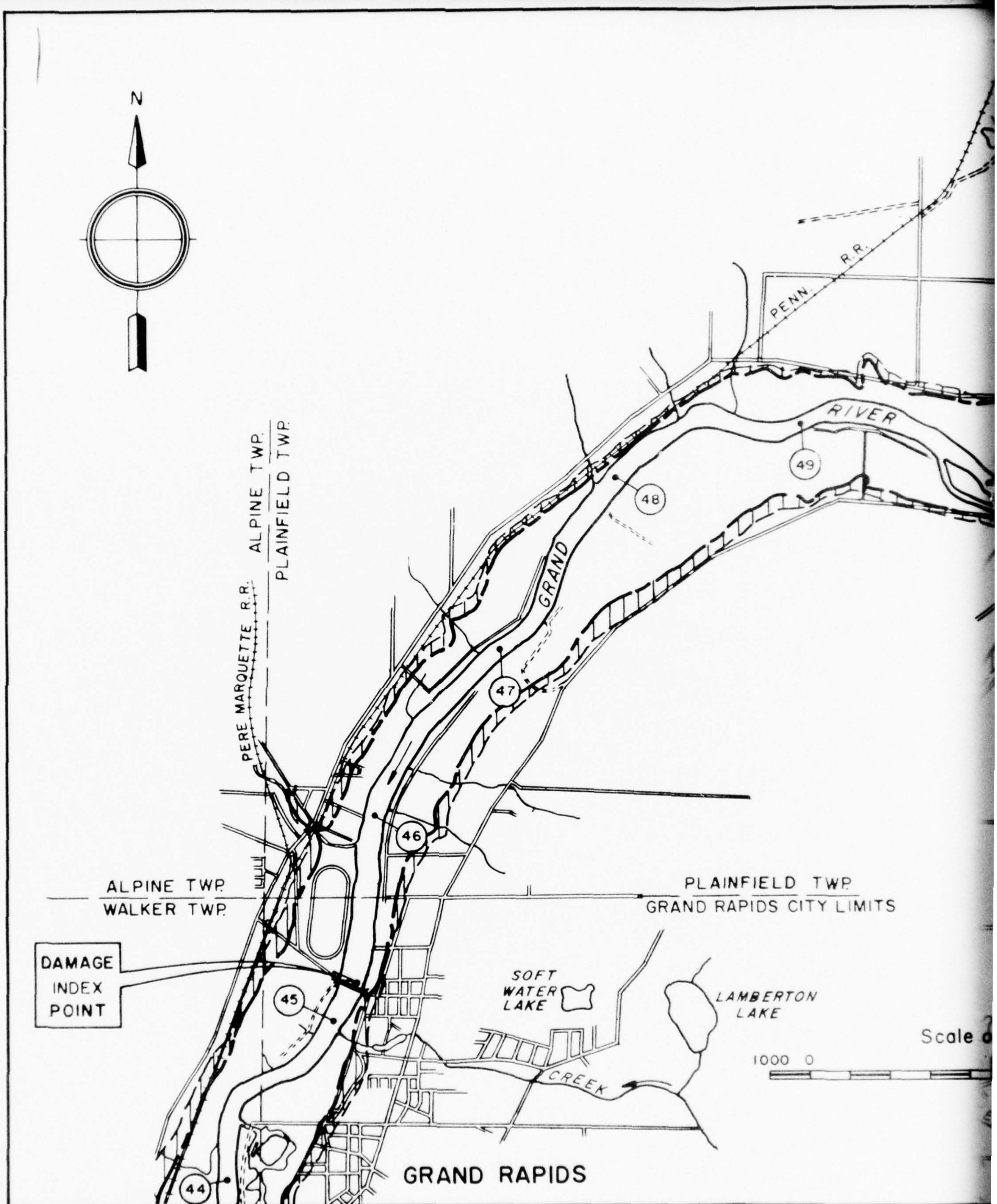
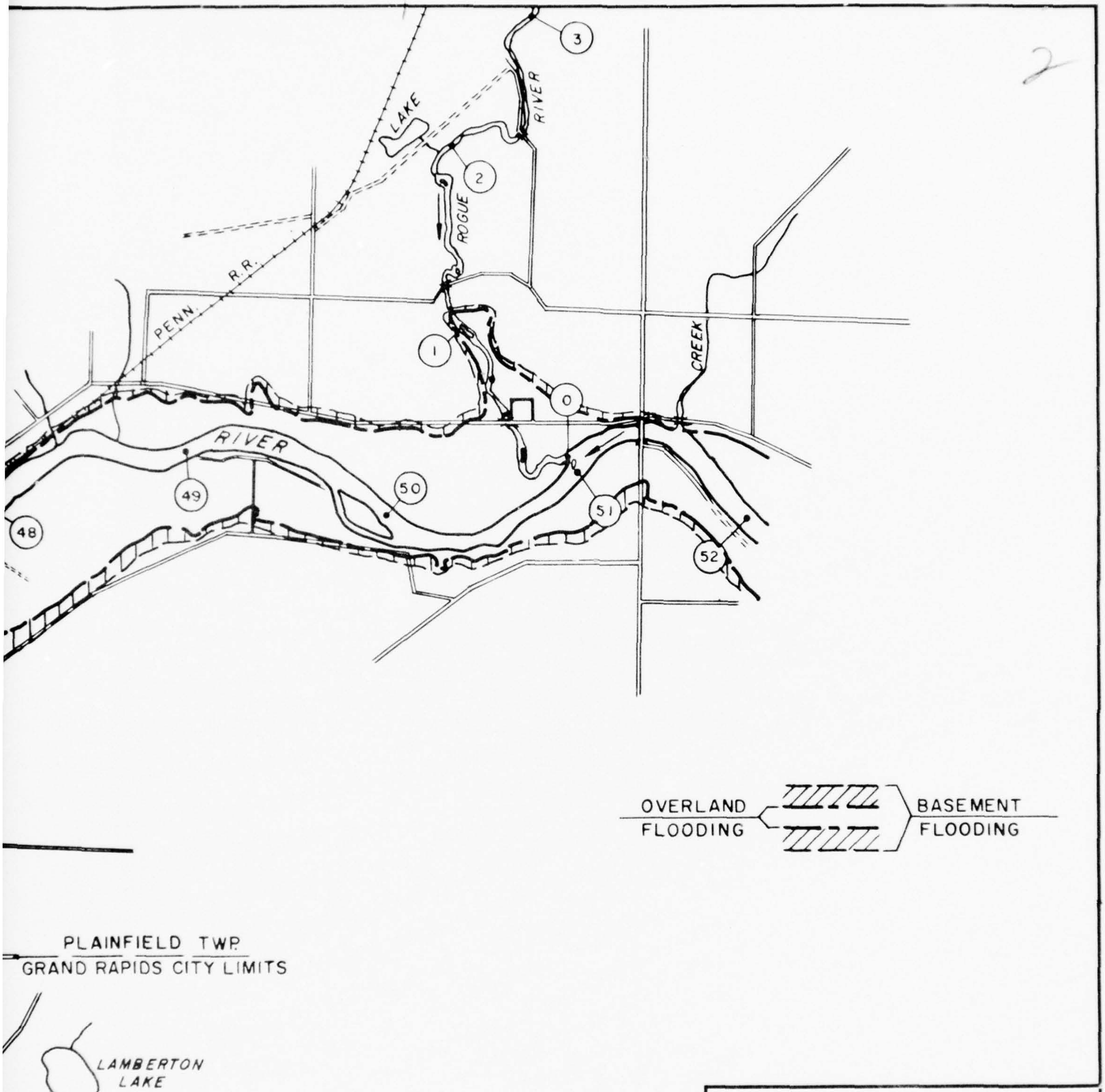

GRAND RIVER BASIN, MICH.
GRAND RAPIDS, MICHIGAN
PLAN OF PROTECTION
FLOOD CONTROL STUDY
SCALE IN FEET
1000 0 1000 2000 3000 4000 5000
EXPRESSWAYS
T7N-R11W
GRAND RAPIDS
KENT CO.
T6N-R11W
PARIS
KENT CO.
RAISE BRIDGES
I 196
GRAND
MARKET AVE.
SEWAGE PUMPING PLANT
CITY LIMITS
PLASTER CR.
WYOMING YARD
SEWAGE DISPOSAL PLANT
BUTTERWORTH ST.
WEALTHY ST.

PLATE H-6

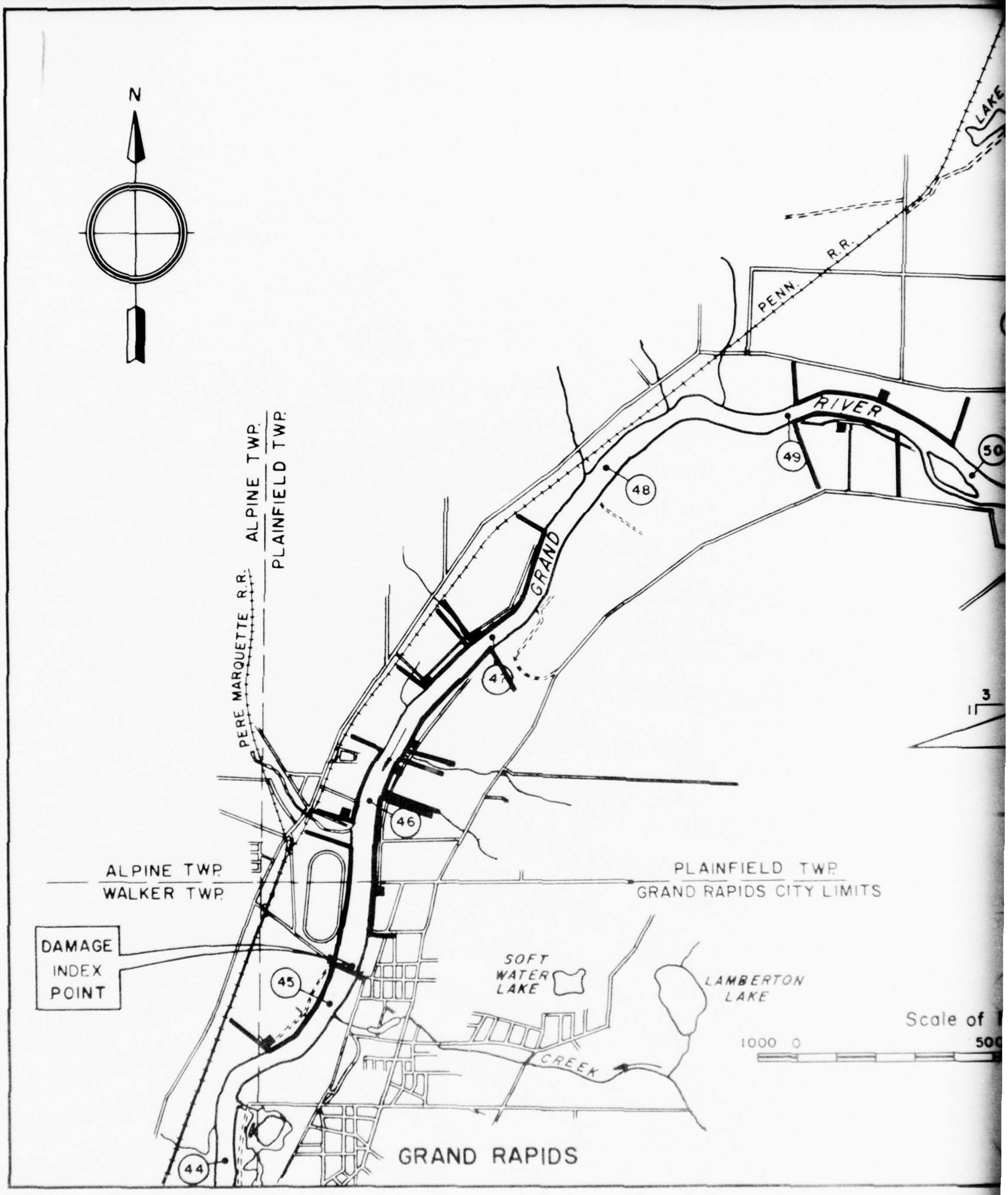

N
PENN. R.R.
RIVER
GRAND
49
48
47
46
45
44
PERE MARQUETTE R.R.
ALPINE TWP.
PLAINFIELD TWP.
ALPINE TWP.
WALKER TWP.
PLAINFIELD TWP.
GRAND RAPIDS CITY LIMITS
DAMAGE
INDEX
POINT
SOFT
WATER
LAKE
LAMBERTON
LAKE
CREEK
Scale
1000 0
GRAND RAPIDS

2



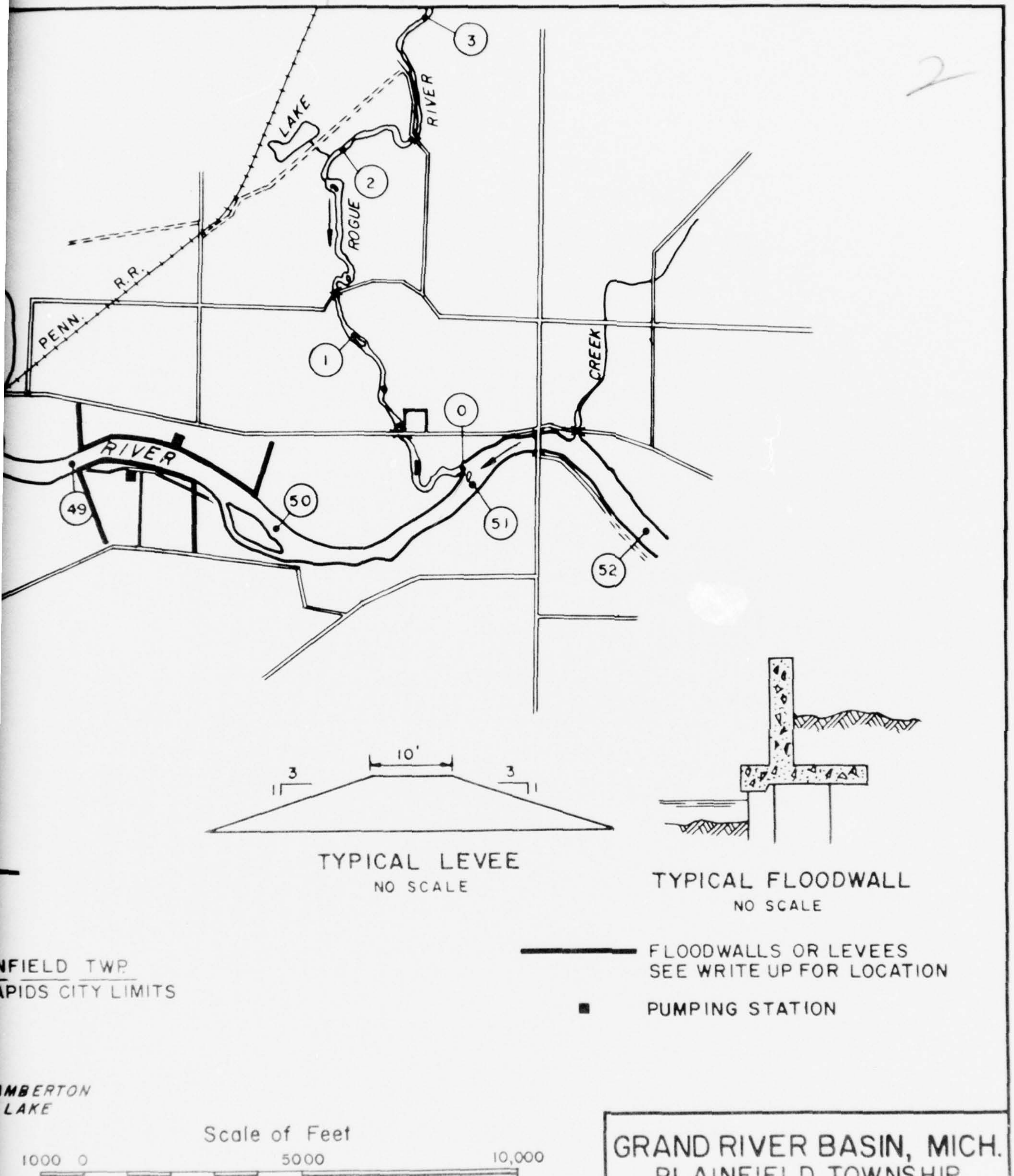
GRAND RIVER BASIN, MICH.
PLAINFIELD TOWNSHIP

1904 FLOOD OUTLINE
FLOOD CONTROL STUDY



N
LAKE
PENN. R.R.
RIVER
GRAND
49
50
48
47
46
45
44
3
ALPINE TWP.
PLAINFIELD TWP.
PERE MARQUETTE R.R.
ALPINE TWP.
WALKER TWP.
PLAINFIELD TWP.
GRAND RAPIDS CITY LIMITS
DAMAGE INDEX POINT
SOFT WATER LAKE
LAMBERTON LAKE
CREEK
Scale of
1000 0
GRAND RAPIDS

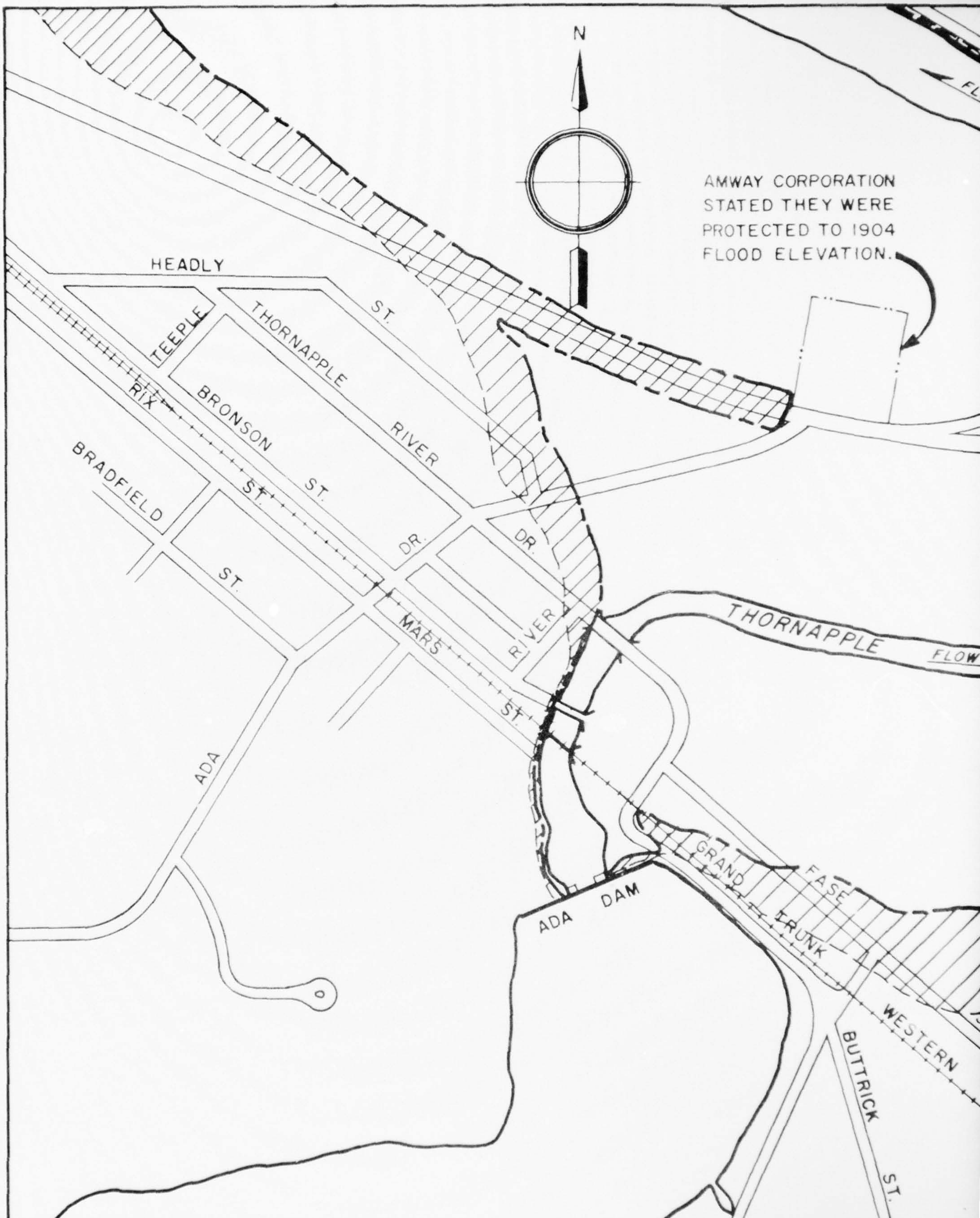
2

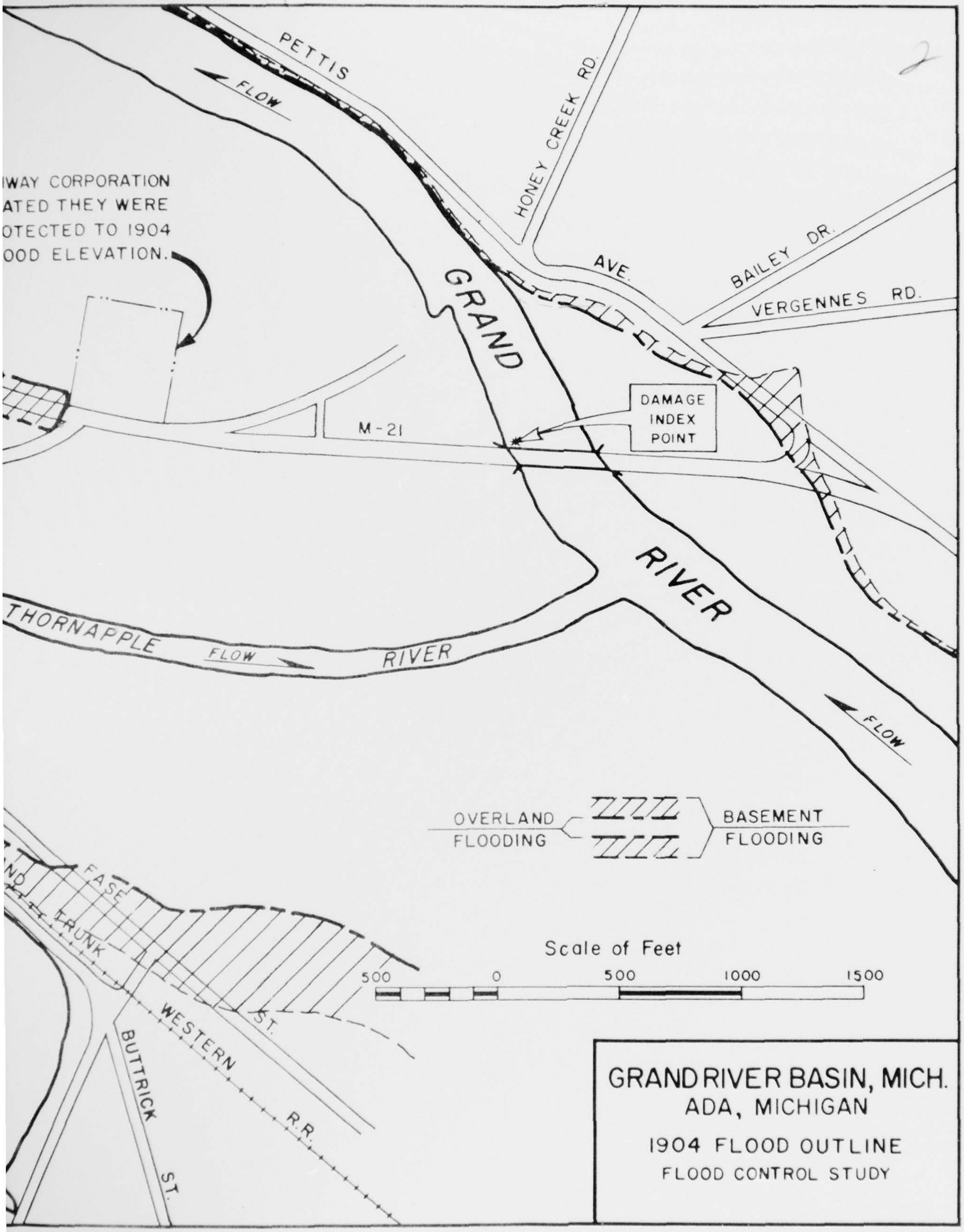


GRAND RIVER BASIN, MICH.
PLAINFIELD TOWNSHIP

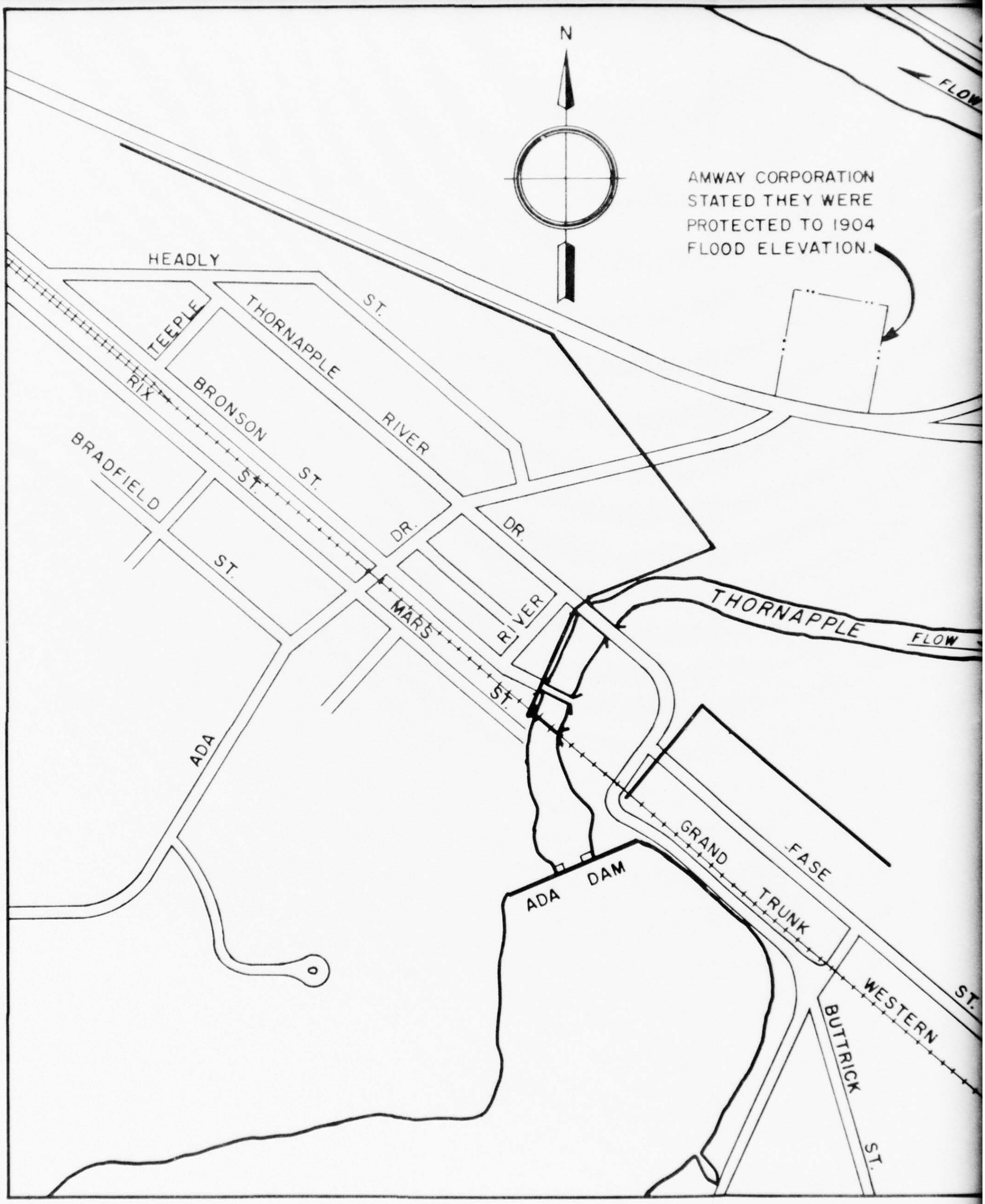
PLAN OF PROTECTION
FLOOD CONTROL STUDY

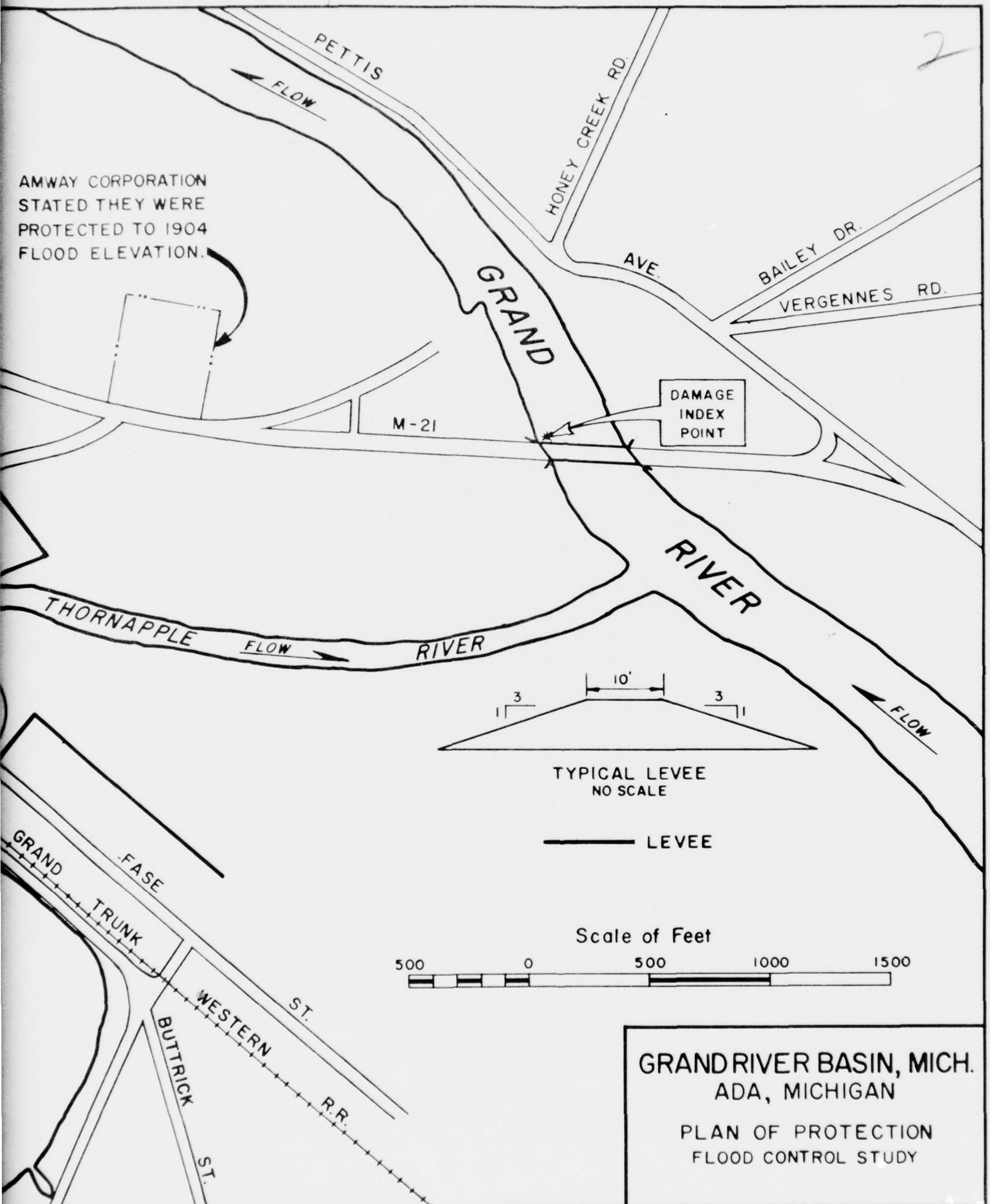
PLATE H-8


N
AMWAY CORPORATION
STATED THEY WERE
PROTECTED TO 1904
FLOOD ELEVATION.
HEADLY
ST.
TEEPLE
THORNAPPLE
RIVER
DR.
RIX
BRONSON
ST.
BRADFIELD
ST.
ST.
DR.
DR.
RIVER
MARS
ST.
THORNAPPLE
FLOW
ADA
GRAND
TRUNK
FASE
WESTERN
ADA DAM
BUTTRICK
ST.



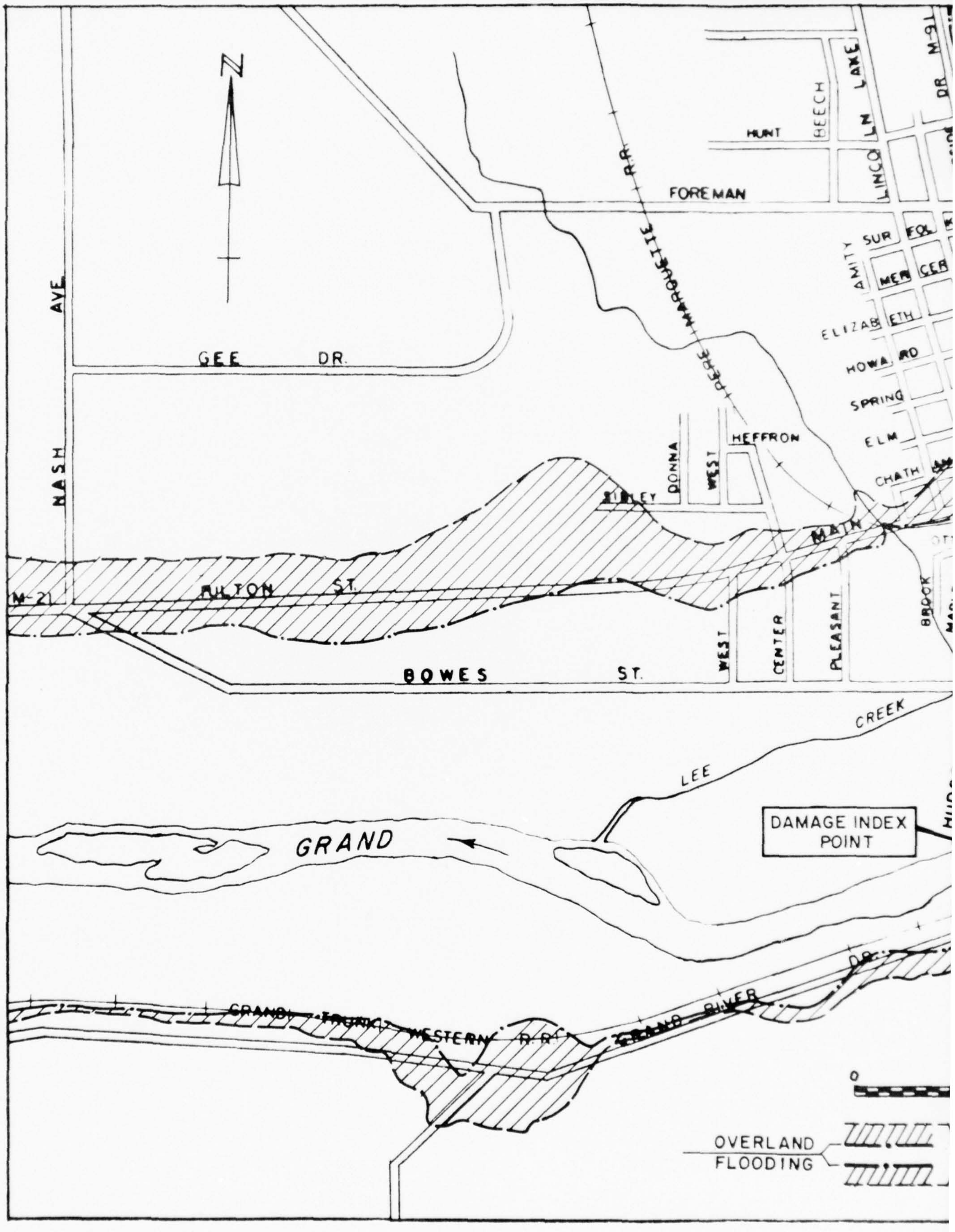
GRAND RIVER BASIN, MICH.
ADA, MICHIGAN
1904 FLOOD OUTLINE
FLOOD CONTROL STUDY


N
AMWAY CORPORATION STATED THEY WERE PROTECTED TO 1904 FLOOD ELEVATION.
FLOW
HEADLY
ST.
TEEPLE
THORNAPPLE
RIVER
RIX
BRONSON
ST.
BRADFIELD
ST.
DR.
DR.
ST.
RIVER
MARS
ST.
THORNAPPLE
FLOW
ADA
ADA DAM
GRAND
TRUNK
WESTERN
FASE
ST.
BUTTRICK
ST.

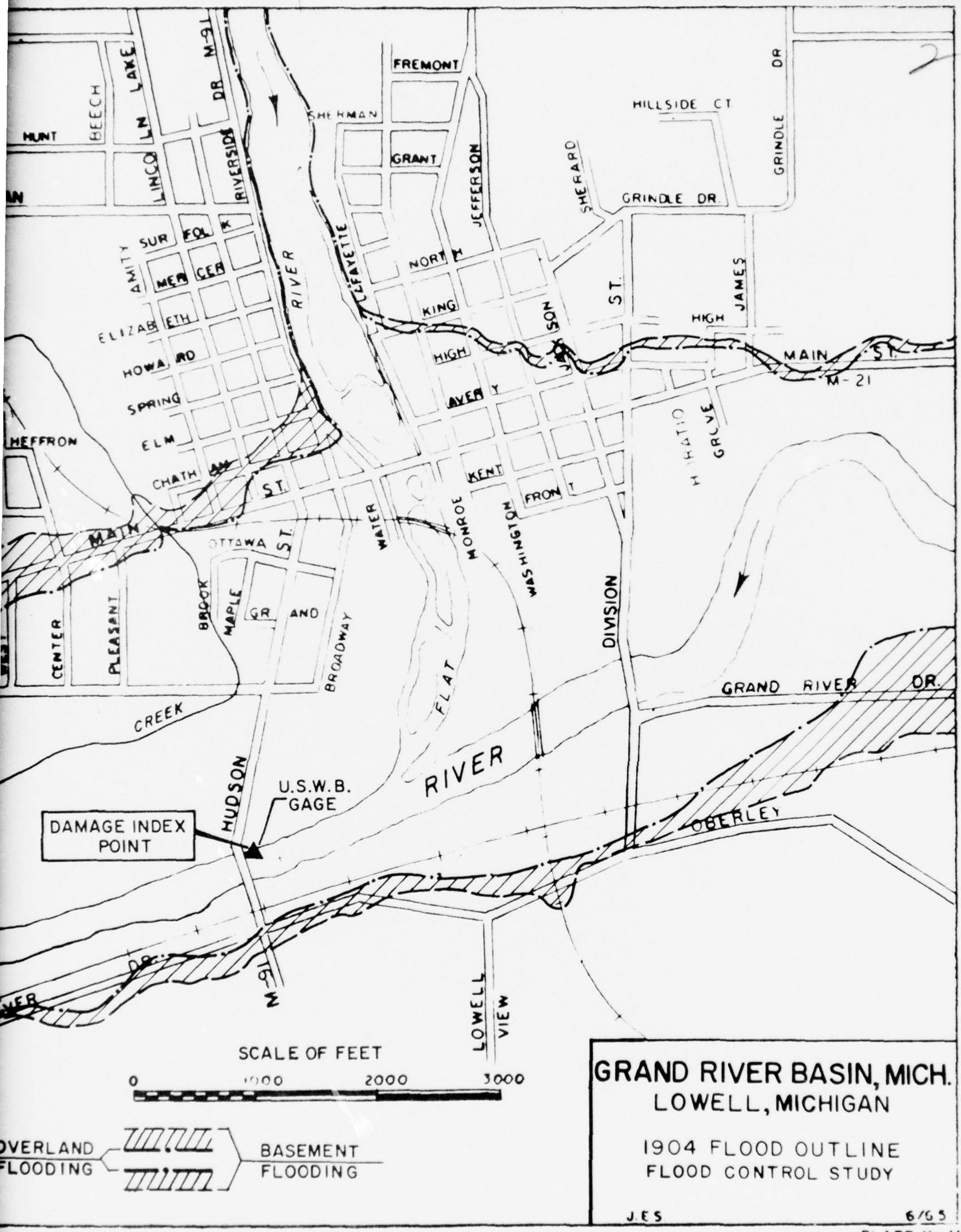


GRAND RIVER BASIN, MICH.
ADA, MICHIGAN
PLAN OF PROTECTION
FLOOD CONTROL STUDY

PLATE H-10

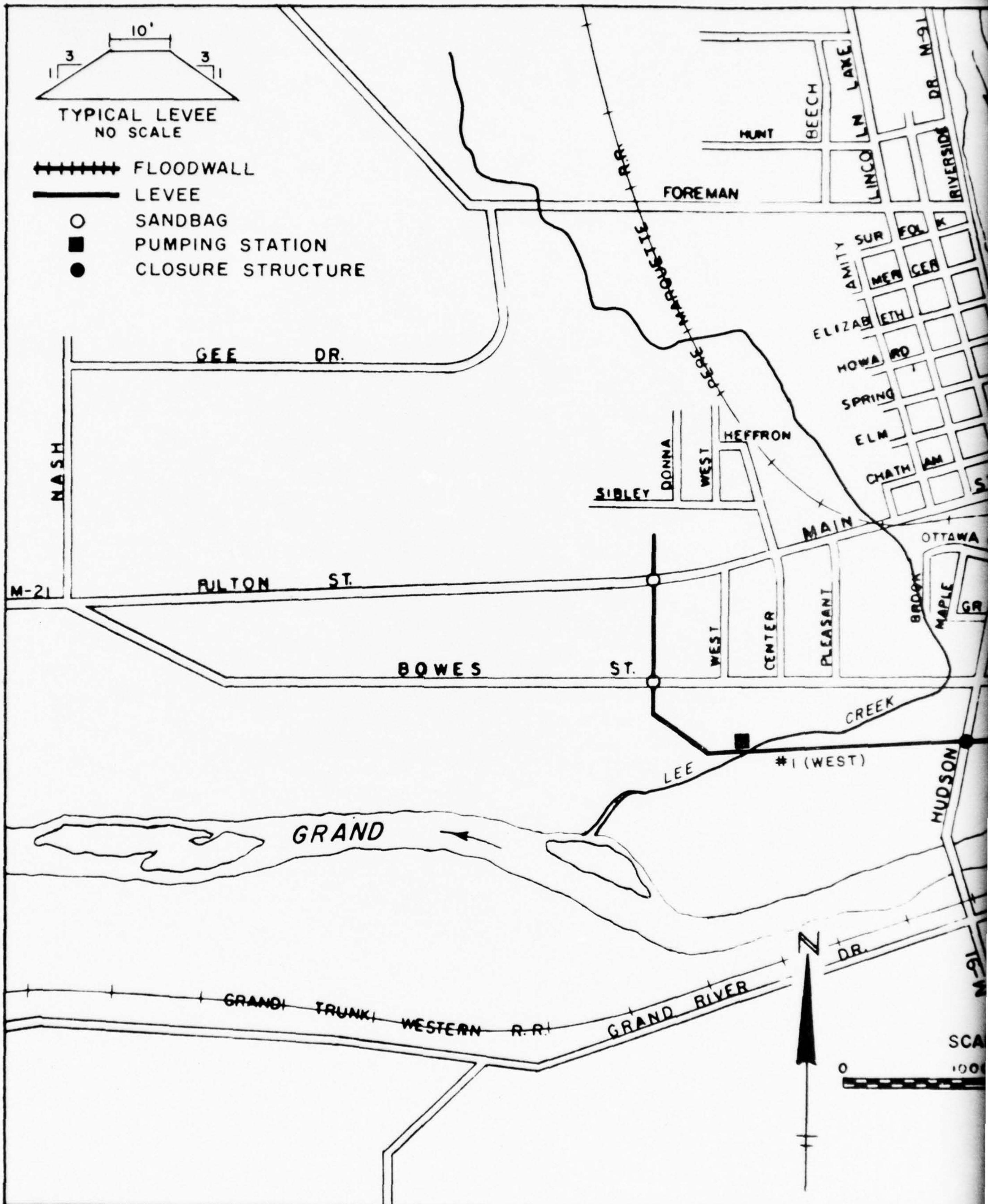


HUNT
BEECH
LAKE
LINCOLN
DR
M-91
FOREMAN
R.R.
PERE MARQUETTE
SUR
FOL
AMITY
MER CER
ELIZABETH
HOWARD
SPRING
ELM
CHATH
HEFFRON
DONNA
WEST
SIBLEY
MAIN
NASH AVE.
GEE DR.
M-21
FULTON ST.
BOWES ST.
WEST
CENTER
PLEASANT
BROOK
LEE CREEK
GRAND
DAMAGE INDEX POINT
GRAND TRUNK WESTERN R.R.
GRAND RIVER DR.
0
OVERLAND FLOODING

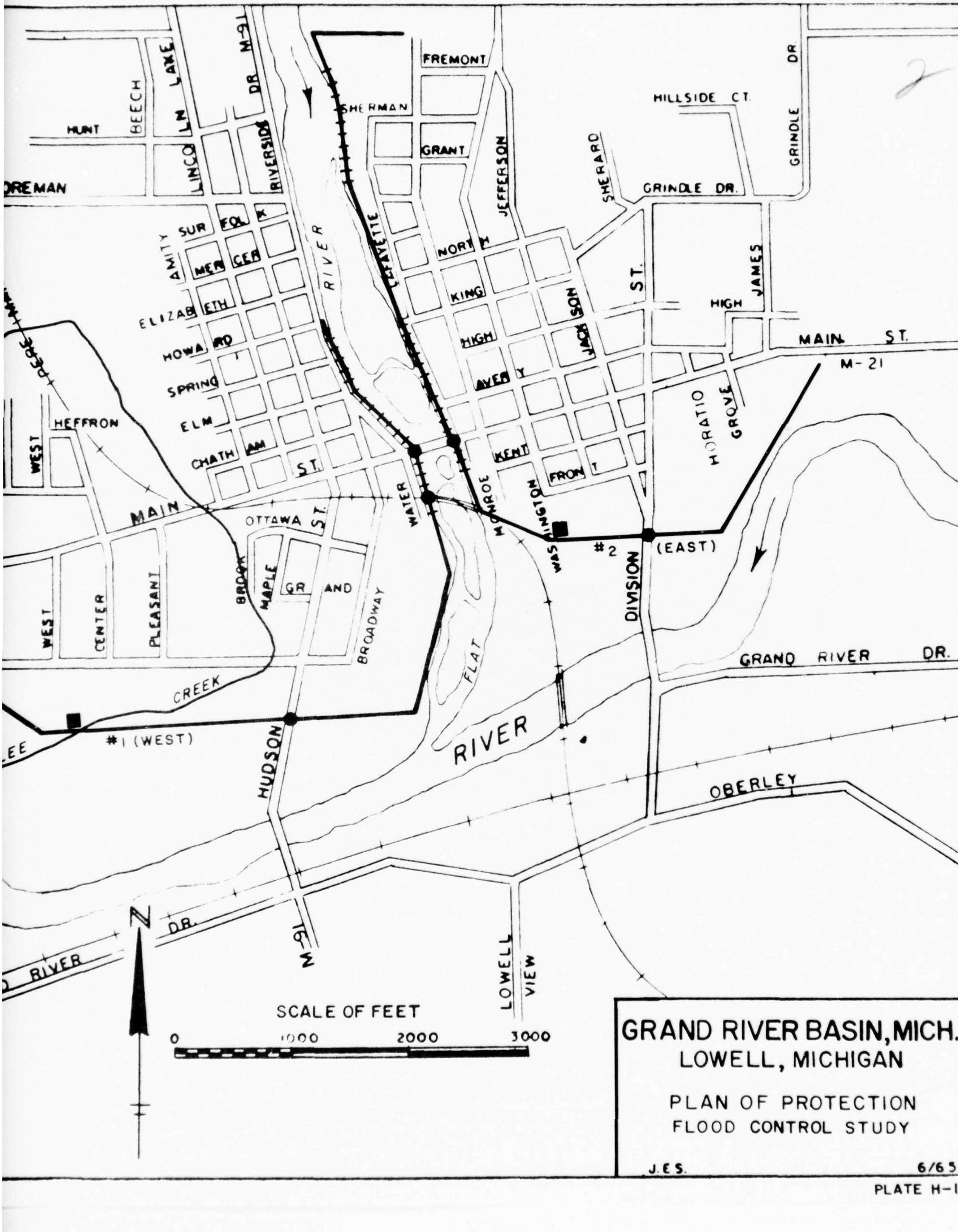


FREMONT
SHERMAN
GRANT
JEFFERSON
LAFAYETTE
HILLSIDE CT.
GRINDLE DR.
GRINDLE
DR.
SHERARD
HUNT
BEECH
LAKE
LINCOLN
M-91
RIVERSIDE DR.
AMITY
SURFOLK
MERCER
ELIZABETH
HOWARD
SPRING
ELM
CHATHAM
HEFFRON
RIVER
NORTH
KING
HIGH
AVERY
JACKSON
ST.
HIGH
JAMES
MAIN ST.
M-21
HORATIO
GROVE
KENT
FRONT
MAIN
ST.
OTTAWA ST.
WATER
MONROE
WASHINGTON
DIVISION
BROOK
MAPLE
GRAND
BROADWAY
CENTER
PLEASANT
FLAT
CREEK
RIVER
GRAND RIVER DR.
HUDSON
U.S.W.B. GAGE
DAMAGE INDEX POINT
OBERLEY
DR.
M-91
LOWELL
VIEW
SCALE OF FEET
0
1000
2000
3000
OVERLAND FLOODING
BASEMENT FLOODING
GRAND RIVER BASIN, MICH.
LOWELL, MICHIGAN
1904 FLOOD OUTLINE
FLOOD CONTROL STUDY
J.ES
6/65

PLATE H-11

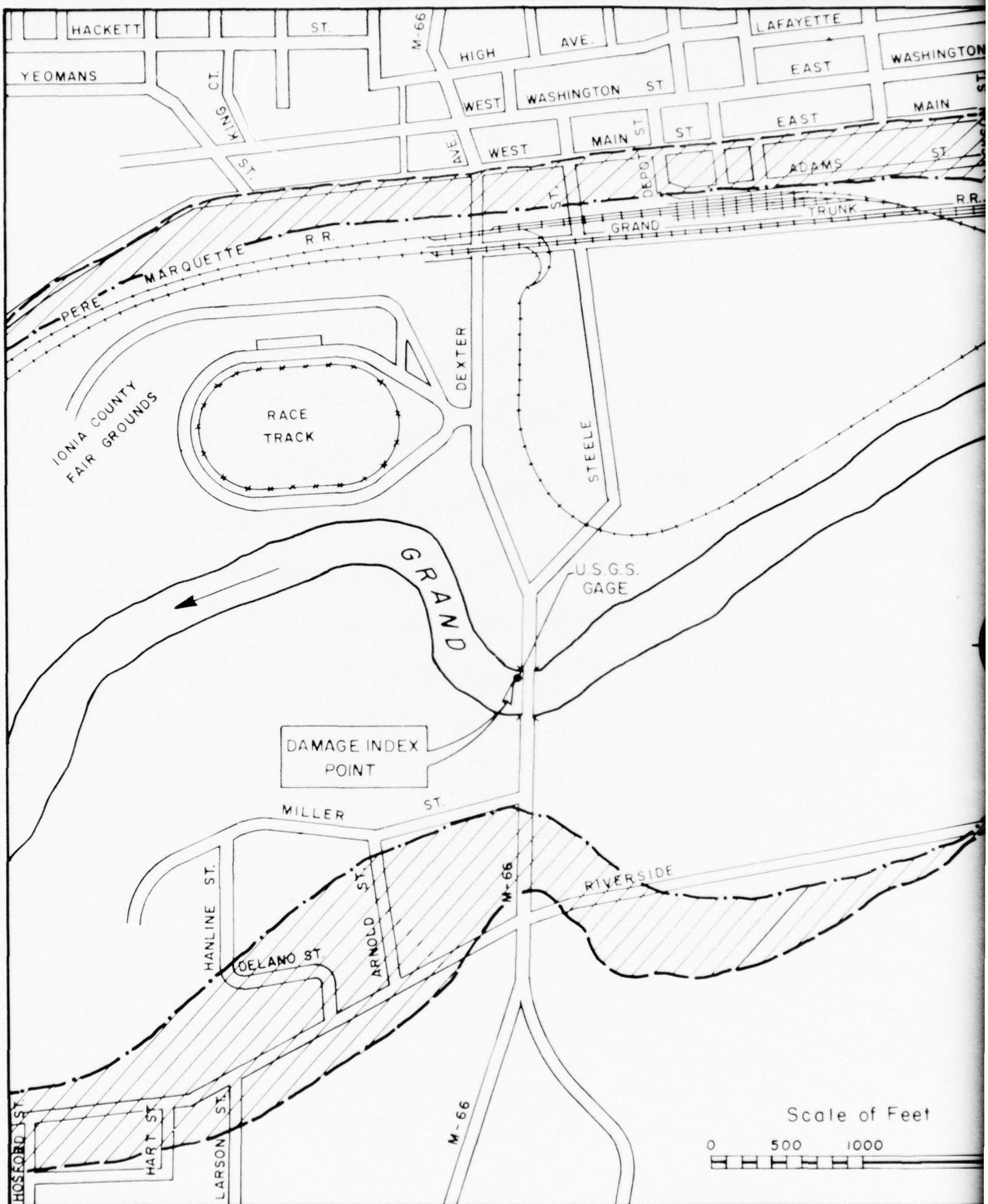


10'
3
1
3
1
TYPICAL LEVEE
NO SCALE
FLOODWALL
LEVEE
SANDBAG
PUMPING STATION
CLOSURE STRUCTURE
GEE DR.
NASH
M-21
FULTON ST.
BOWES ST.
FOREMAN
HUNT
BEECH
LINCOLN
LAKE
DR
M-91
RIVERSIDE
PERE MARQUETTE R.R.
AMITY
SURFOLK
MERCER
ELIZABETH
HOWARD
SPRING
ELM
CHATHAM
HEFFRON
DONNA
WEST
SIBLEY
MAIN
OTTAWA
BROOK
MAPLE
WEST
CENTER
PLEASANT
CREEK
LEE
#1 (WEST)
HUDSON
GRAND
N
DR.
GRAND RIVER
GRAND TRUNK WESTERN R.R.
M-91
0

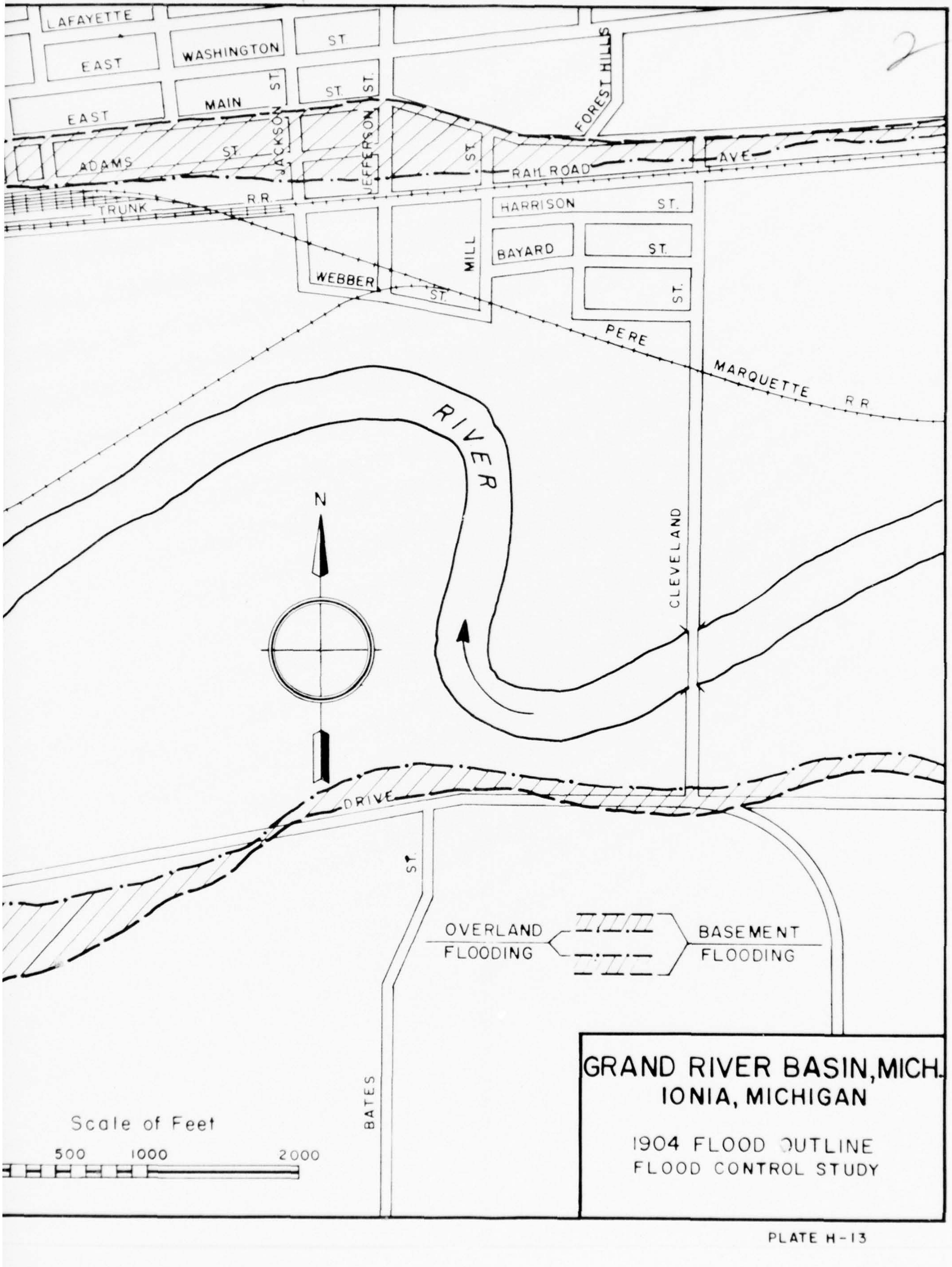


GRAND RIVER BASIN, MICH.
LOWELL, MICHIGAN

PLAN OF PROTECTION
FLOOD CONTROL STUDY

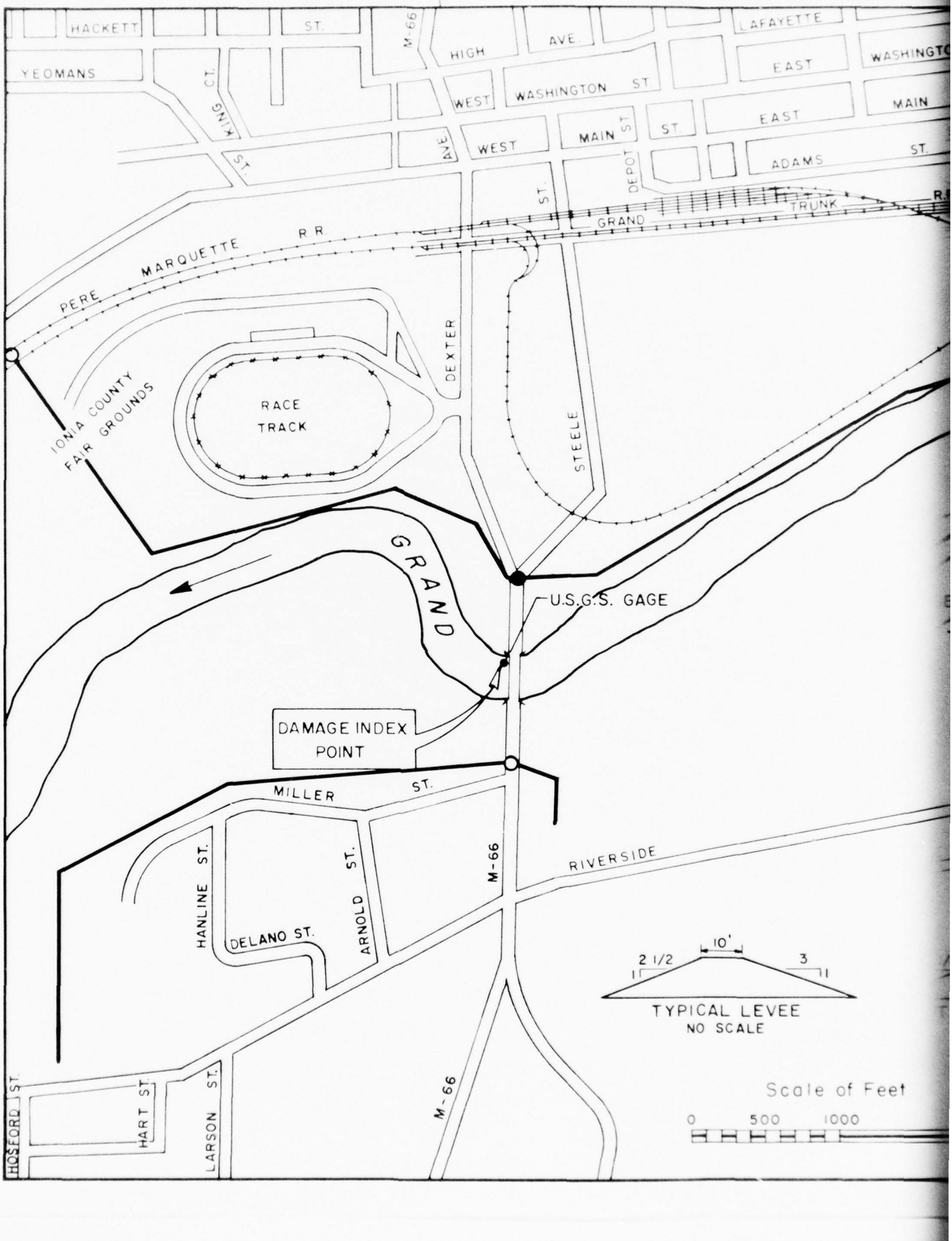


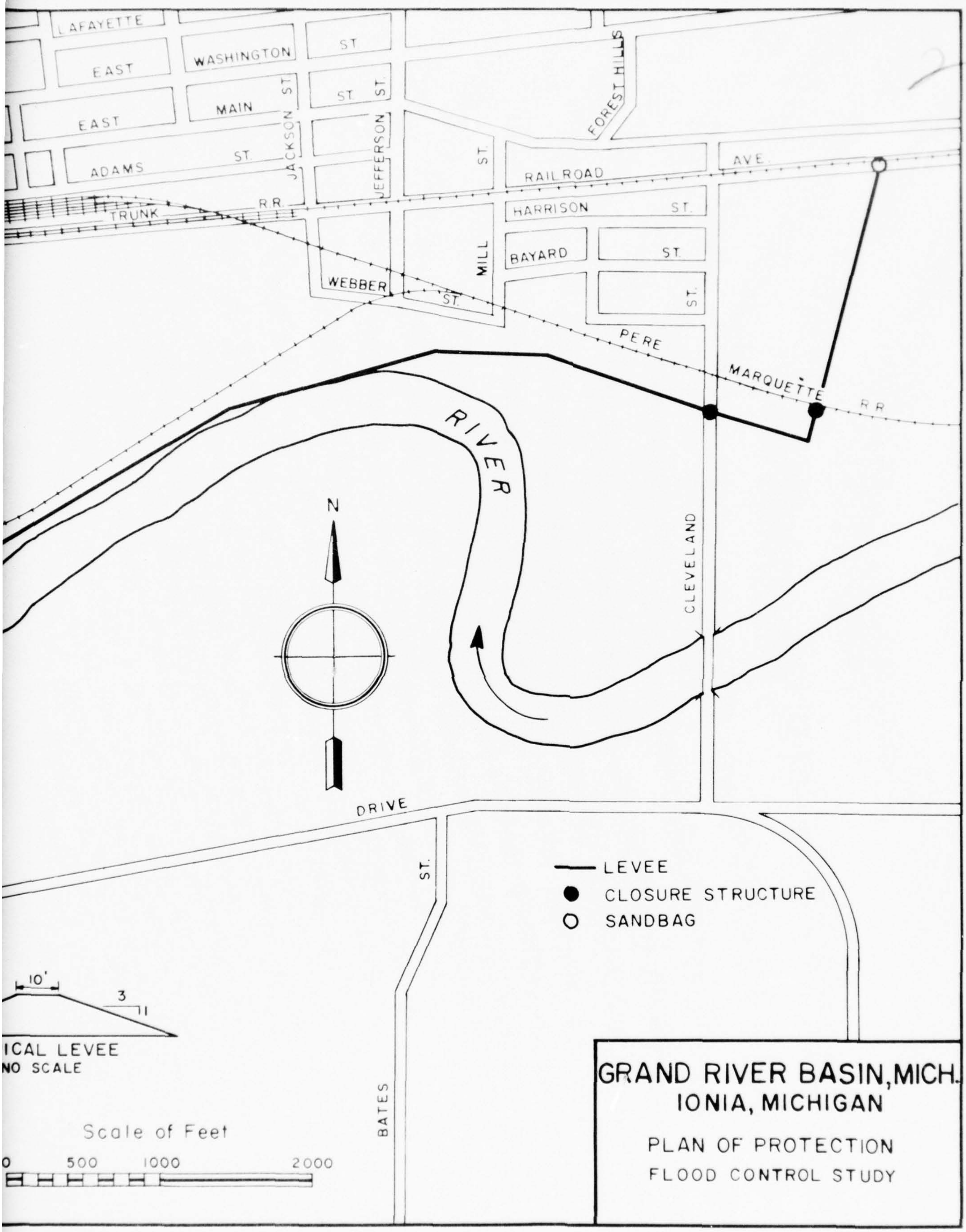
HACKETT
ST.
M-66
LAFAYETTE
HIGH
AVE.
EAST
WASHINGTON
YEOMANS
KING CT.
WEST
WASHINGTON ST.
MAIN
ST.
ST.
EAST
AVE.
WEST
MAIN
DEPOT ST.
ADAMS
ST.
ST.
R.R.
TRUNK
GRAND
R.R.
MARQUETTE
PERE
DEXTER
IONIA COUNTY
FAIR GROUNDS
RACE
TRACK
STEELE
GRAND
U.S.G.S.
GAGE
DAMAGE INDEX
POINT
MILLER
ST.
HANLINE ST.
ARNOLD ST.
M-66
RIVERSIDE
DELANO ST.
HOSFORD ST.
HART ST.
LARSON ST.
M-66
Scale of Feet
0
500
1000



LAFAYETTE
EAST
WASHINGTON
ST.
EAST
MAIN
ST.
JACKSON
ST.
JEFFERSON
ST.
FOREST HILLS
ADAMS
ST.
ST.
RAILROAD
AVE.
TRUNK
R.R.
HARRISON
ST.
BAYARD
ST.
MILL
WEBBER
ST.
ST.
PERE
MARQUETTE
R.R.
RIVER
N
CLEVELAND
DRIVE
ST.
BATES
OVERLAND
FLOODING
BASEMENT
FLOODING
Scale of Feet
500
1000
2000
GRAND RIVER BASIN, MICH.
IONIA, MICHIGAN
1904 FLOOD OUTLINE
FLOOD CONTROL STUDY

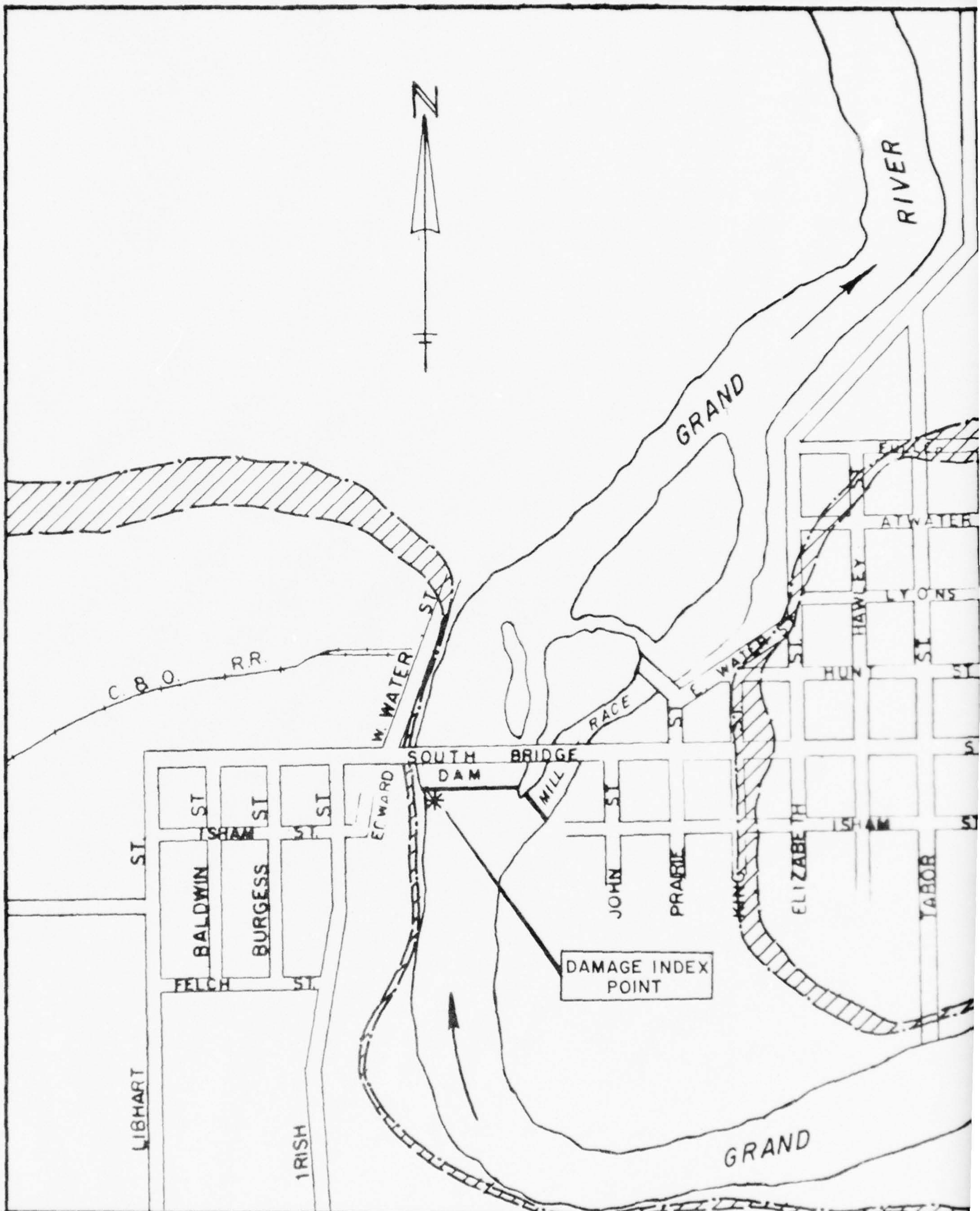
PLATE H-13


HACKETT
ST.
M-66
HIGH
AVE.
LAFAYETTE
EAST
WASHINGTO
YEOMANS
KING CT.
WEST
WASHINGTON ST
EAST
MAIN
ST.
AVE.
WEST
MAIN
ST
ST.
ADAMS
ST.
DEPOT ST
ST.
TRUNK
GRAND
PERE
MARQUETTE
R R
DEXTER
RACE
TRACK
IONIA COUNTY
FAIR GROUNDS
STEELE
GRAND
U.S.G.S. GAGE
DAMAGE INDEX
POINT
MILLER
ST.
HANLINE ST.
ARNOLD ST.
M-66
RIVERSIDE
DELANO ST.
10'
2 1/2
1
3
1
TYPICAL LEVEE
NO SCALE
HOSFORD ST.
HART ST.
LARSON ST.
M-66
Scale of Feet
0
500
1000

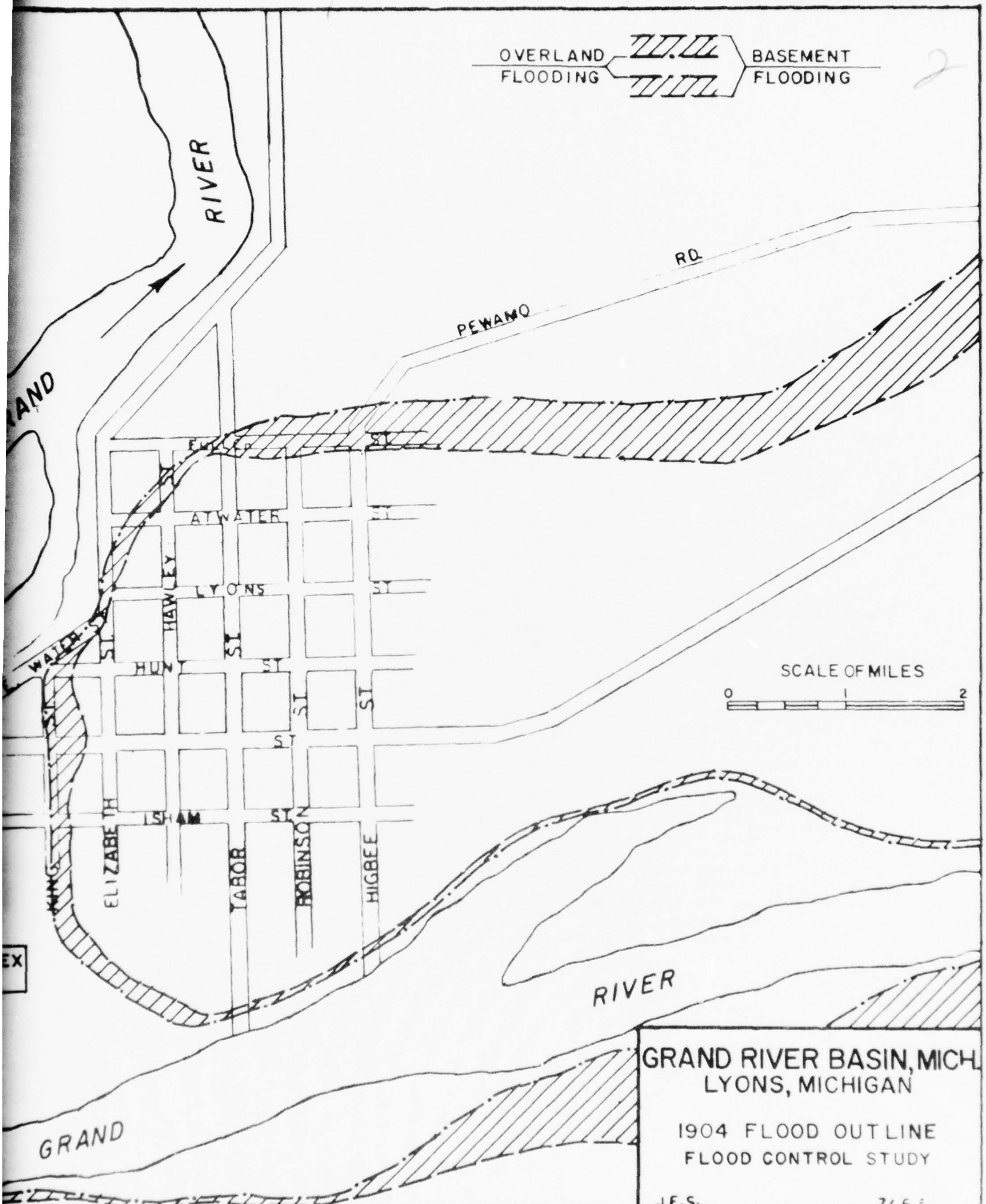


GRAND RIVER BASIN, MICH.
IONIA, MICHIGAN
PLAN OF PROTECTION
FLOOD CONTROL STUDY

PLATE H-14



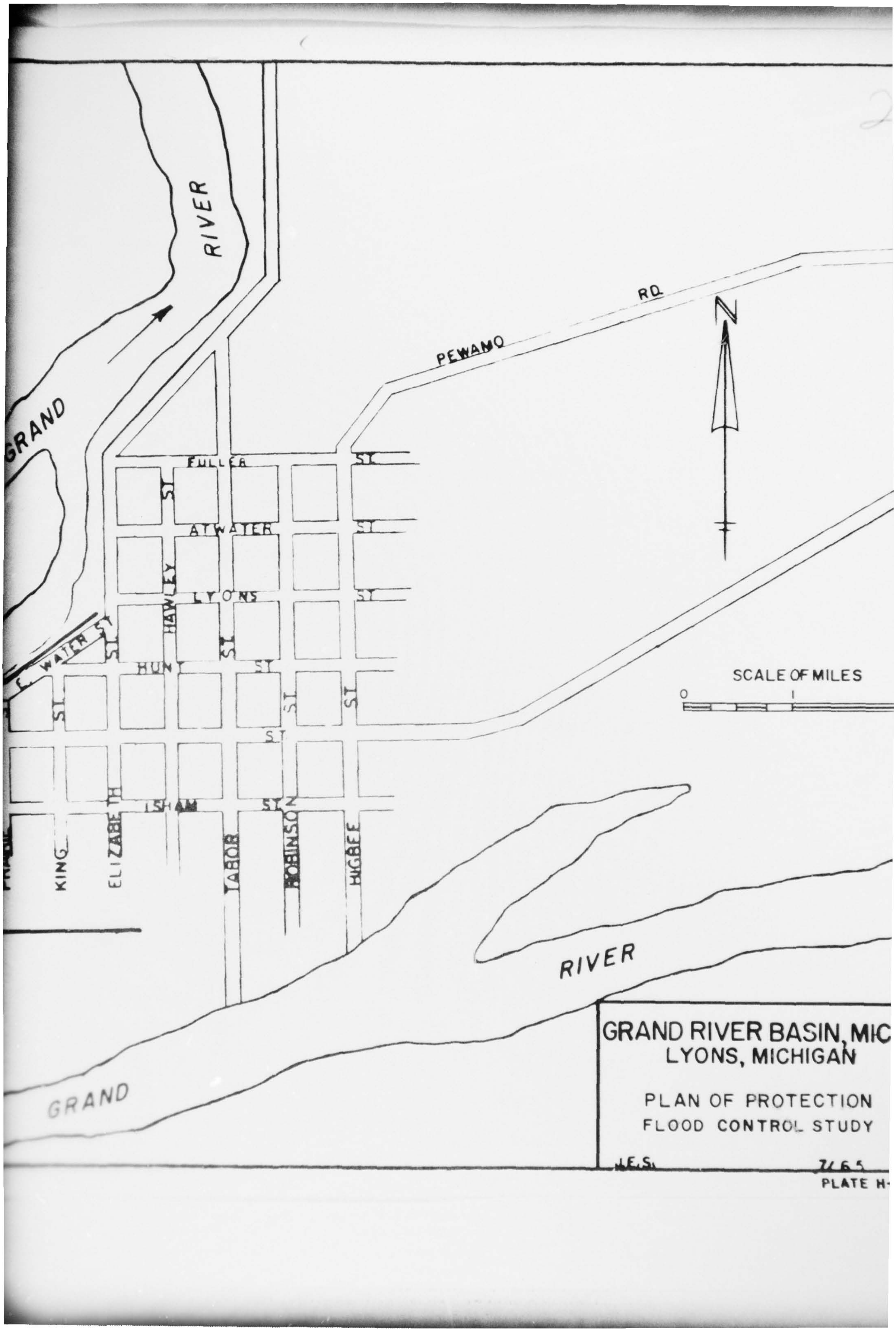
N
GRAND
RIVER
C.B.O. R.R.
W. WATER ST
SOUTH BRIDGE
DAM
MILL
RACE
E. WATER
ATWATER
LYONS
HAWLEY
HUNT ST
ST
ISHAM ST
ISHAM ST
BALDWIN ST
BURGESS ST
ST
EDWARD
FELCH ST
LIBHART ST
IRISH
JOHN ST
PRAIRIE ST
KING ST
ELIZABETH
TABOR
DAMAGE INDEX POINT
GRAND

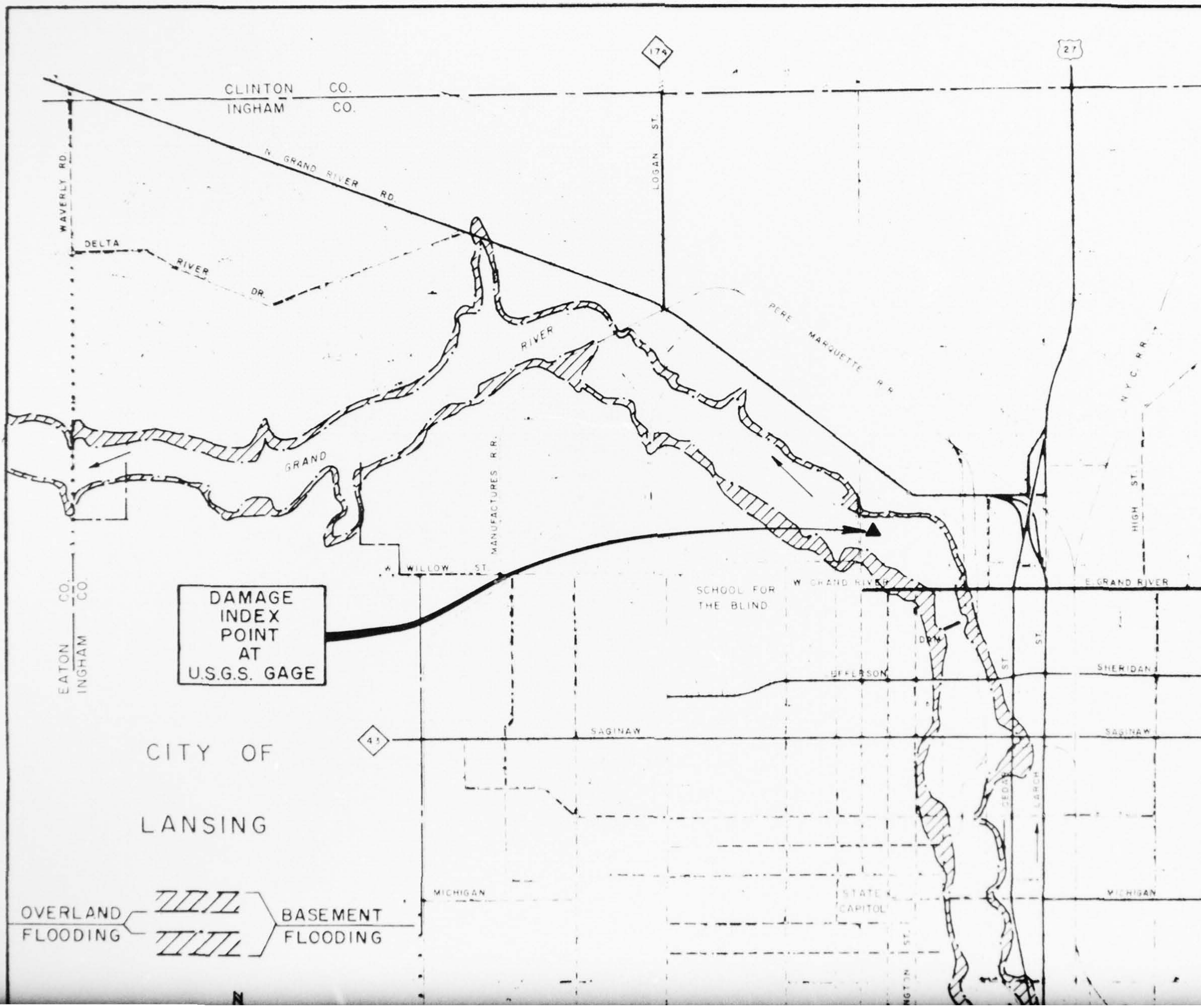


OVERLAND FLOODING
BASEMENT FLOODING
RIVER
GRAND
RD.
PEWAMO
ATWATER
ST
LYONS
ST
HAWLEY
ST
HUNT
ST
ST
ST
ST
ISHAM
ST
KING
ELIZABETH
TABOR
ROBINSON
HIGBEE
SCALE OF MILES
0
1
2
RIVER
GRAND
GRAND RIVER BASIN, MICH.
LYONS, MICHIGAN
1904 FLOOD OUTLINE
FLOOD CONTROL STUDY
J.E.S.

PLATE H-15

10'
2
1
2
1
TYPICAL LEVEE
NO SCALE
LEVEE
PUMP STATION
GRAND
RIVER
GRAND
C. & O. RR.
W. WATER ST.
E. WATER ST.
MILL RACE
SOUTH BRIDGE
DAM
MILL
FULLER
ATWATER
LYON
HUNT
HAWLEY
ST.
ISHAM ST.
BALDWIN ST.
BURGESS ST.
FELCH ST.
LIBHART ST.
IRISH
EDWARD
JOHN ST.
PRAIRIE
KING
ELIZABETH
TABOR
ISHAM


GRAND RIVER
GRAND
PEWAMO RD
N
FULLER ST
ATWATER ST
LYONS ST
HAWLEY ST
E. WATER ST
HUNT ST
ISHAM ST
KING
ELIZABETH
TABOR
ROBINSON
HIGBEE
SCALE OF MILES
0
1
RIVER
GRAND
GRAND RIVER BASIN, MIC
LYONS, MICHIGAN
PLAN OF PROTECTION
FLOOD CONTROL STUDY
J.E.S.
7/65
PLATE H-



CLINTON CO.
INGHAM CO.
174
27
N. GRAND RIVER RD.
LOGAN ST.
WAVERLY RD.
DELTA RIVER DR.
PERE MARQUETTE R.R.
N.Y.C. R.R.
GRAND RIVER
MANUFACTURES R.R.
HIGH ST.
W. WILLOW ST.
W. GRAND RIVER
E. GRAND RIVER
SCHOOL FOR THE BLIND
EATON CO.
INGHAM CO.
DAMAGE INDEX POINT AT U.S.G.S. GAGE
SHERIDAN
SAGINAW
43
CEDAR ST.
LARCH ST.
CITY OF LANSING
MICHIGAN
STATE CAPITOL
OVERLAND FLOODING
BASEMENT FLOODING

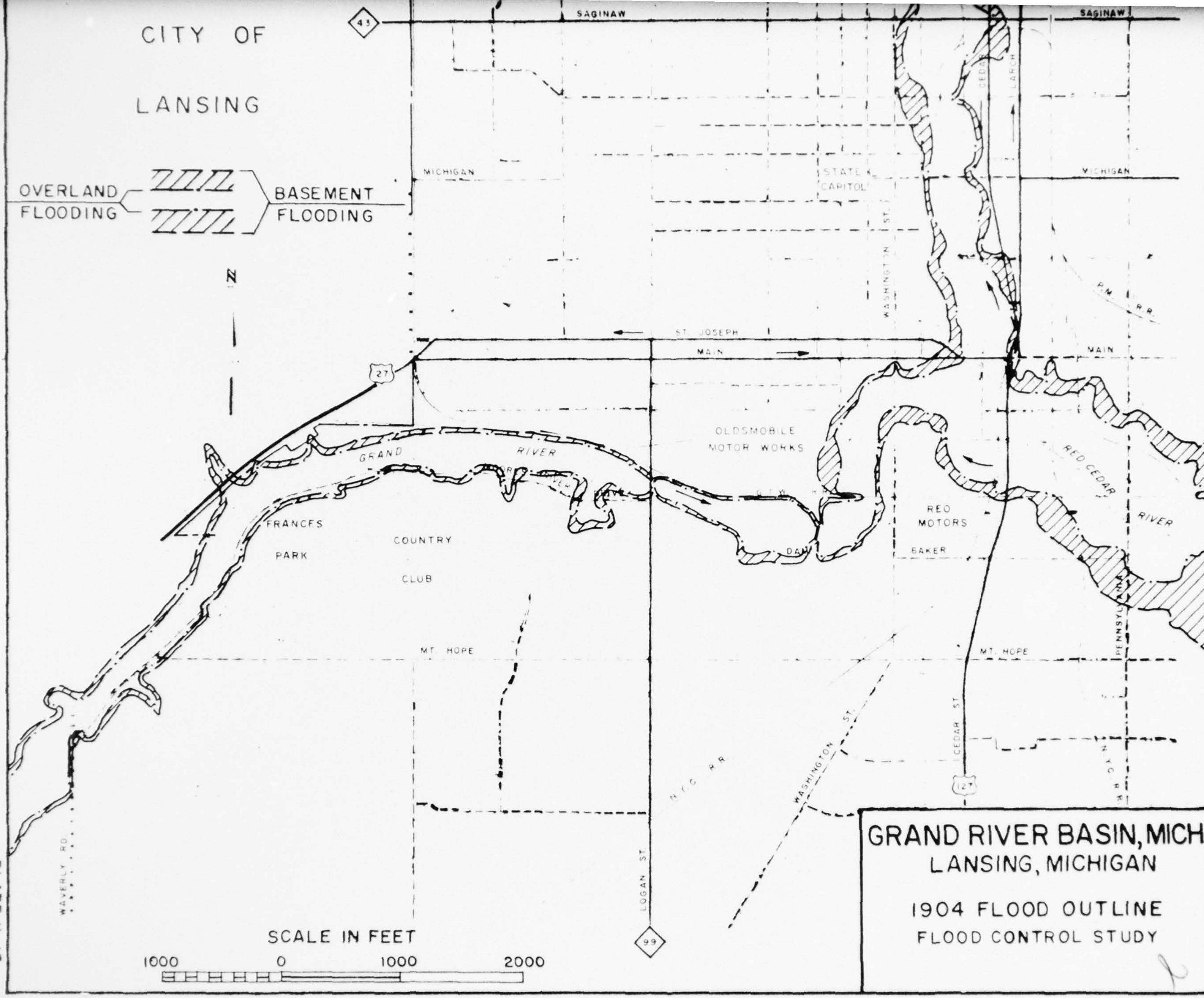
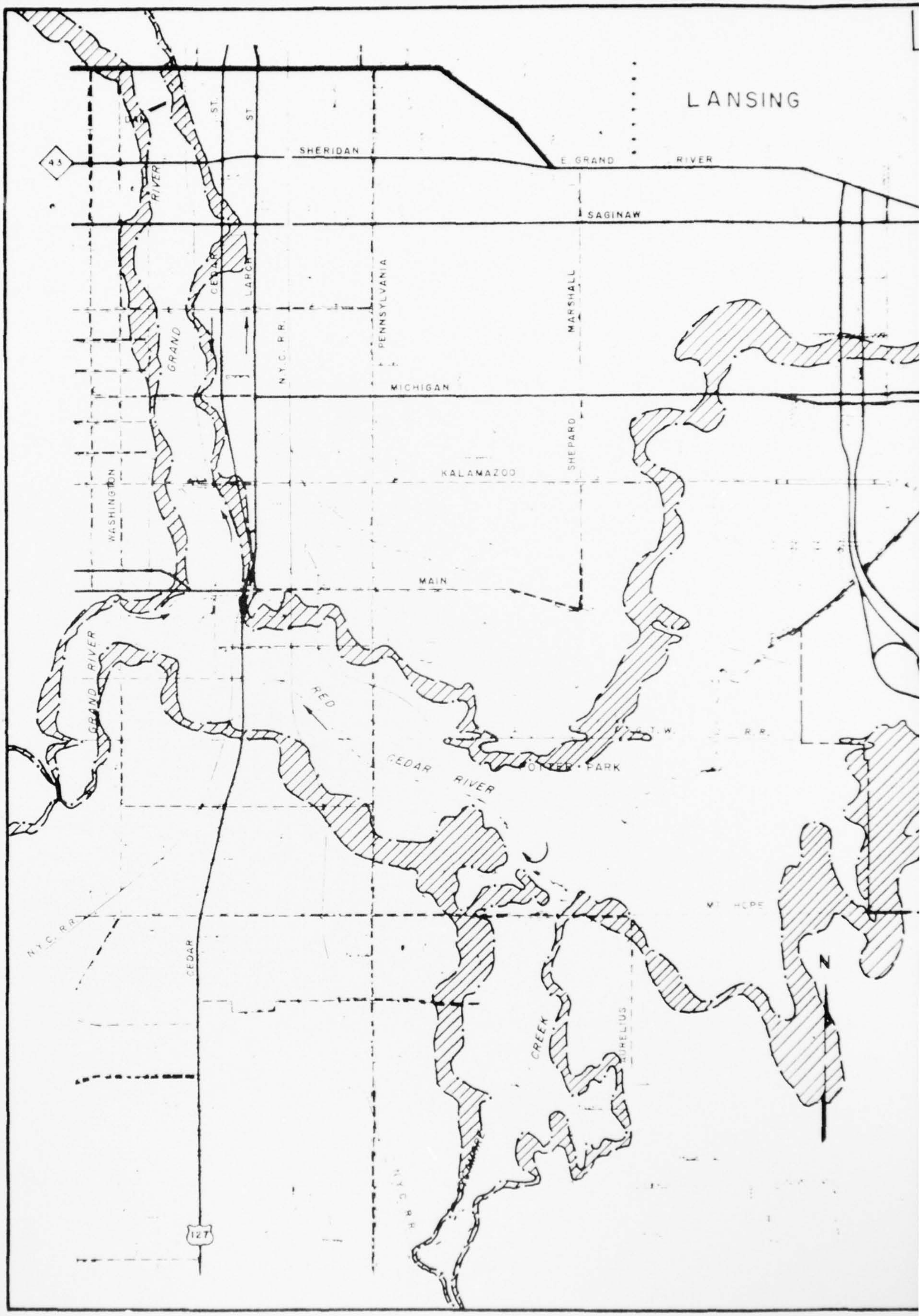
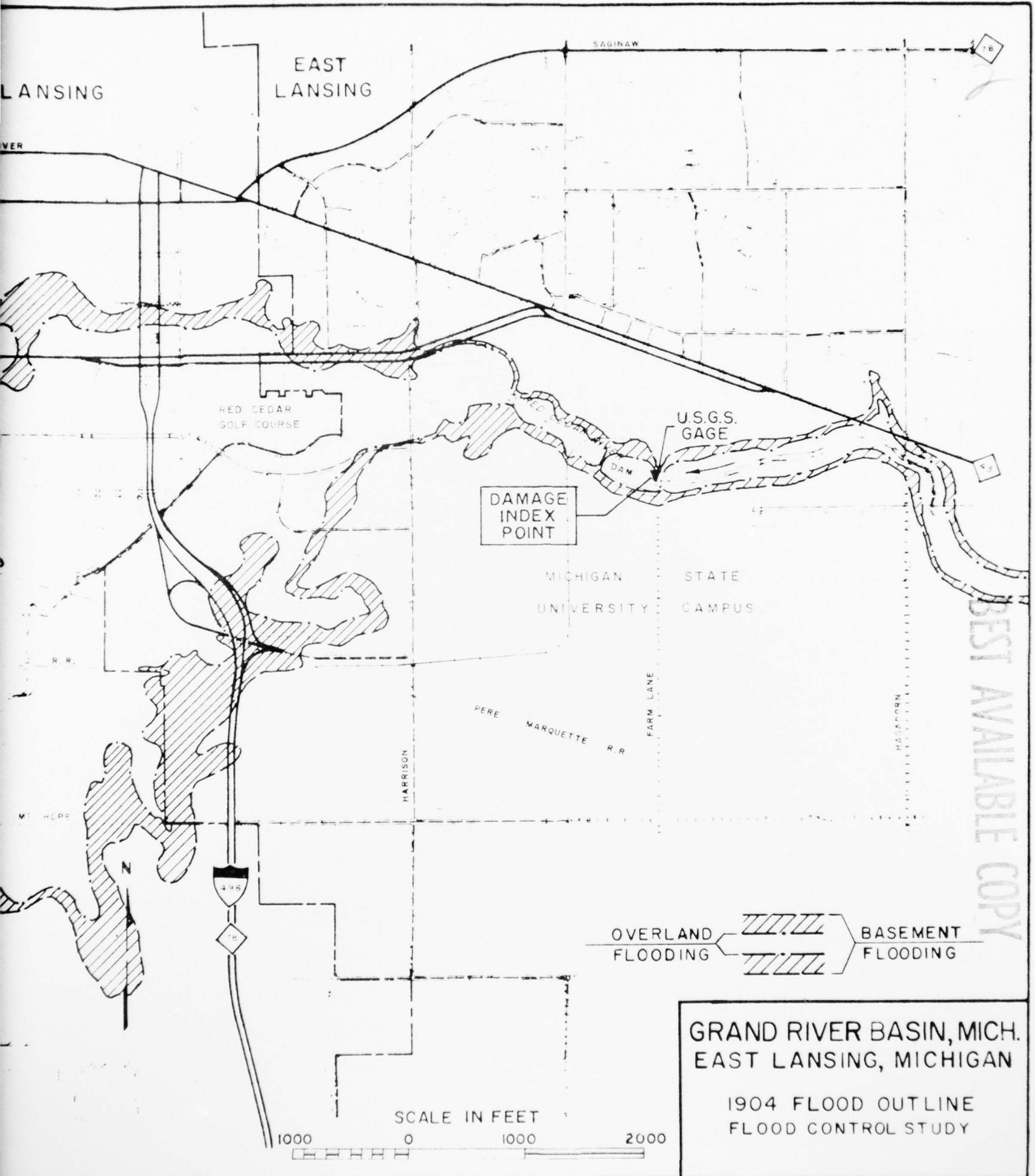
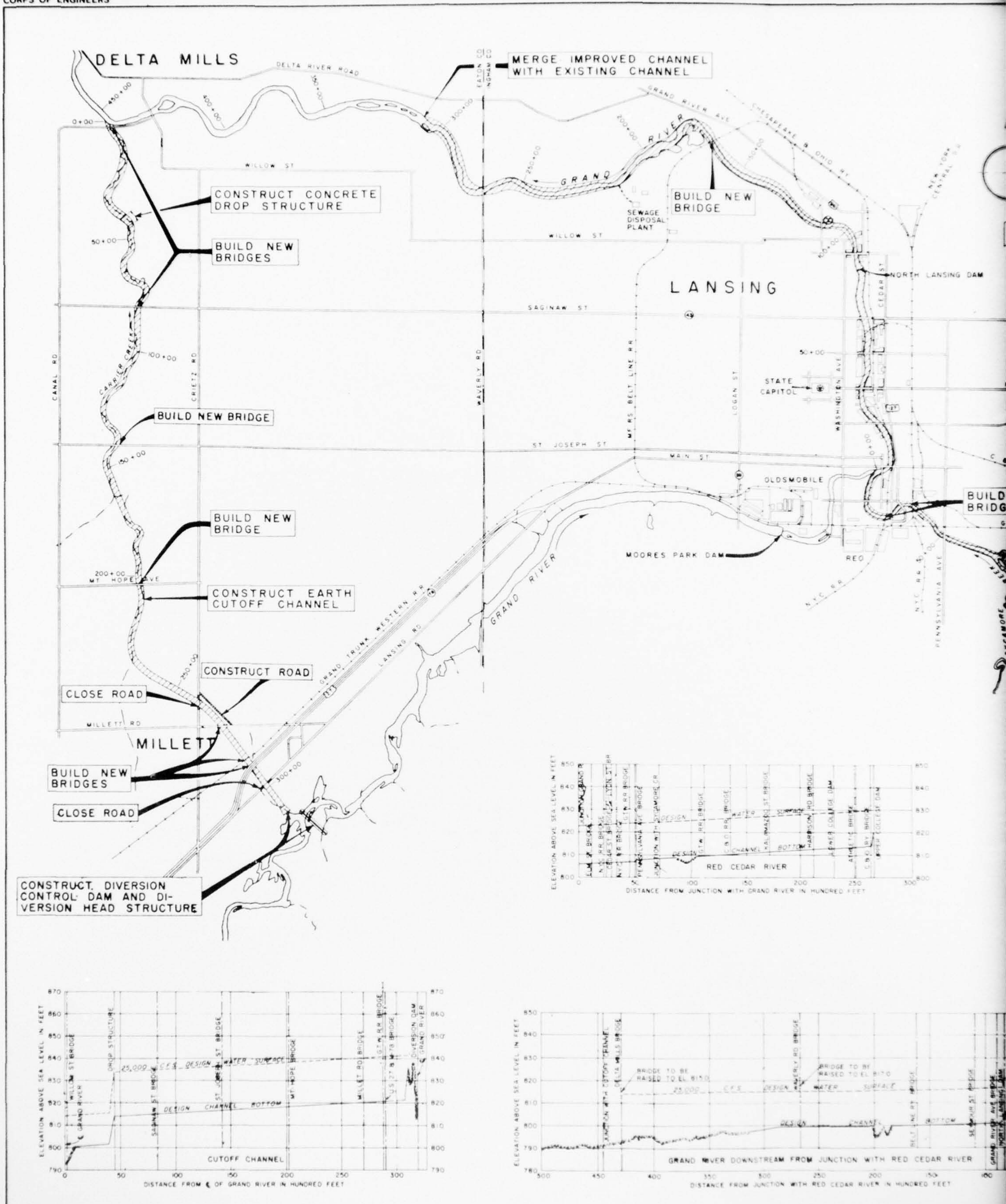

CITY OF
LANSING
OVERLAND
FLOODING
BASEMENT
FLOODING
N
SAGINAW
MICHIGAN
STATE
CAPITOL
WASHINGTON ST.
CEDAR
LARCH
P.M. R.R.
ST. JOSEPH
MAIN
OLDSMOBILE
MOTOR WORKS
GRAND
RIVER
RED CEDAR
RIVER
REO
MOTORS
BAKER
DAM
FRANCES
PARK
COUNTRY
CLUB
MT. HOPE
PENNSYLVANIA
CEDAR ST.
WASHINGTON ST.
N.Y.C. R.R.
LOGAN ST.
WAVERLY RD.
43
27
99
127
SCALE IN FEET
1000
0
1000
2000
GRAND RIVER BASIN, MICH.
LANSING, MICHIGAN
1904 FLOOD OUTLINE
FLOOD CONTROL STUDY

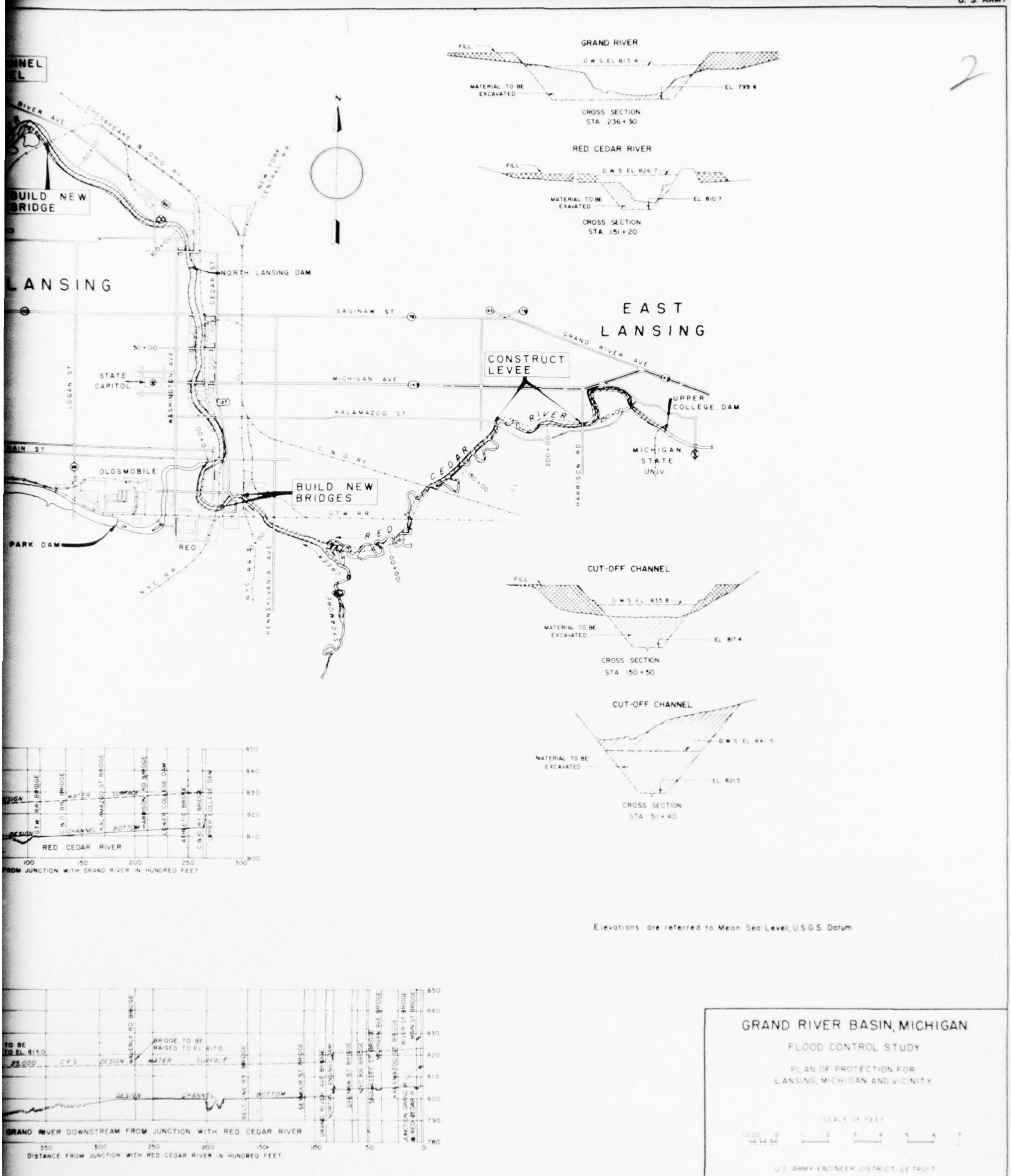
PLATE H-17


LANSING
SHERIDAN
E. GRAND
RIVER
SAGINAW
43
GRAND
RIVER
CEDAR
ST.
ST.
PENNSYLVANIA
MARSHALL
N.Y.C. R.R.
MICHIGAN
SHEPARD
KALAMAZOO
WASHINGTON
MAIN
GRAND RIVER
RED
CEDAR
RIVER
OTTER PARK
R.R.
N.Y.C. R.R.
CEDAR
MT. HOPE
N
CREEK
127
N.Y.C. R.R.

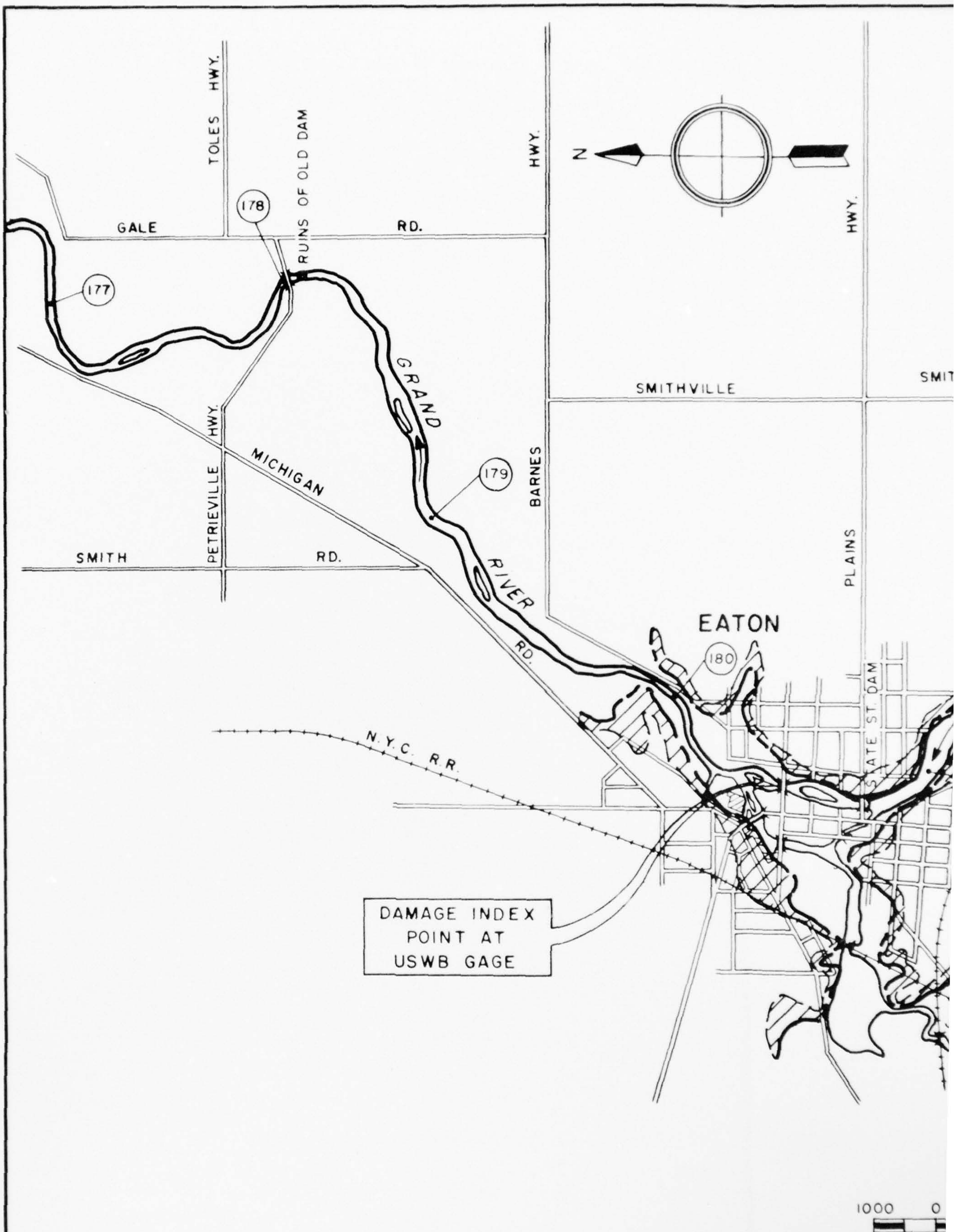

LANSING
EAST LANSING
SAGINAW
RED CEDAR GOLF COURSE
U.S.G.S. GAGE
DAM
DAMAGE INDEX POINT
MICHIGAN STATE UNIVERSITY CAMPUS
PERE MARQUETTE R.R.
FARM LANE
HARRISON
HAGADORN
R.R.
N
496
78
OVERLAND FLOODING
BASEMENT FLOODING
SCALE IN FEET
1000 0 1000 2000
GRAND RIVER BASIN, MICH.
EAST LANSING, MICHIGAN
1904 FLOOD OUTLINE
FLOOD CONTROL STUDY

CORPS OF ENGINEERS

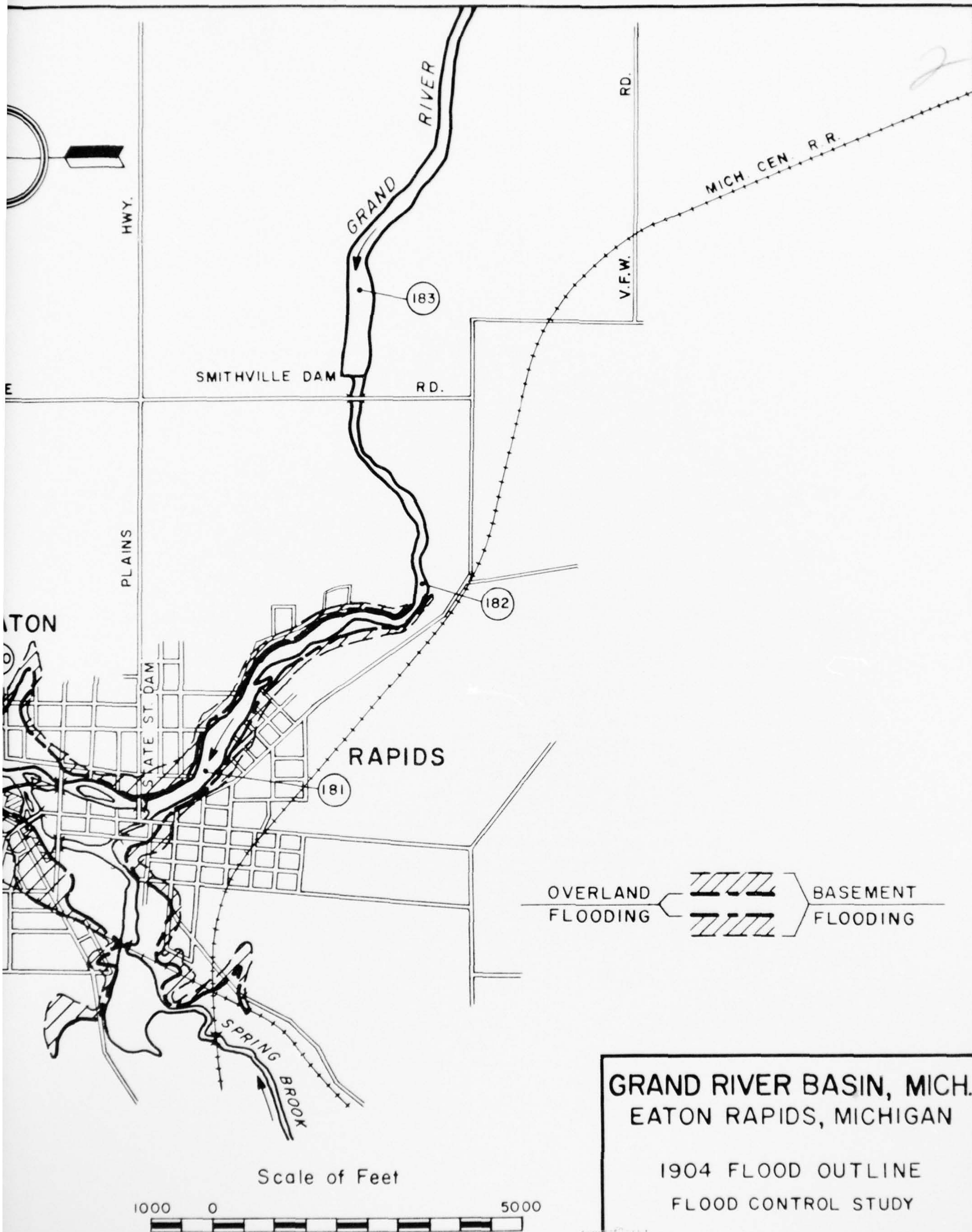




2
GRAND RIVER
FILL
D.W.S. EL 815.4
MATERIAL TO BE EXCAVATED
EL 799.4
CROSS SECTION
STA. 236+30
RED CEDAR RIVER
FILL
D.W.S. EL 826.7
MATERIAL TO BE EXAVATED
EL 810.7
CROSS SECTION
STA. 151+20
BUILD NEW BRIDGE
LANSING
NORTH LANSING DAM
EAST LANSING
SAGINAW ST
GRAND RIVER AVE
CONSTRUCT LEVEE
STATE CAPITOL
MICHIGAN AVE
KALAMAZOO ST
UPPER COLLEGE DAM
MICHIGAN STATE UNIV.
OLDSMOBILE
BUILD NEW BRIDGES
G.T.W. RR
RED CEDAR RIVER
PARK DAM
SYCAMORE
CUT-OFF CHANNEL
FILL
D.W.S. EL 835.8
MATERIAL TO BE EXCAVATED
EL 817.4
CROSS SECTION
STA. 150+50
CUT-OFF CHANNEL
D.W.S. EL 841.5
MATERIAL TO BE EXCAVATED
EL 821.5
CROSS SECTION
STA. 311+40
DESIGN WATER SURFACE
DESIGN CHANNEL BOTTOM
RED CEDAR RIVER
FROM JUNCTION WITH GRAND RIVER IN HUNDRED FEET
Elevations are referred to Mean Sea Level, U.S.G.S. Datum
BRIDGE TO BE RAISED TO EL 817.0
25,000 C.F.S. DESIGN WATER SURFACE
DESIGN CHANNEL BOTTOM
GRAND RIVER DOWNSTREAM FROM JUNCTION WITH RED CEDAR RIVER
DISTANCE FROM JUNCTION WITH RED CEDAR RIVER IN HUNDRED FEET
GRAND RIVER BASIN, MICHIGAN
FLOOD CONTROL STUDY
PLAN OF PROTECTION FOR LANSING, MICHIGAN AND VICINITY
SCALE OF FEET
U.S. ARMY ENGINEER DISTRICT, DETROIT



TOLES HWY.
RUINS OF OLD DAM
178
177
GALE
RD.
HWY.
N
HWY.
GRAND
RIVER
SMITHVILLE
SMIT
PETRIEVILLE HWY.
MICHIGAN
RD.
179
BARNES
SMITH
RD.
PLAINS
EATON
180
STATE ST. DAM
N.Y.C. R.R.
DAMAGE INDEX POINT AT USWB GAGE
1000
0

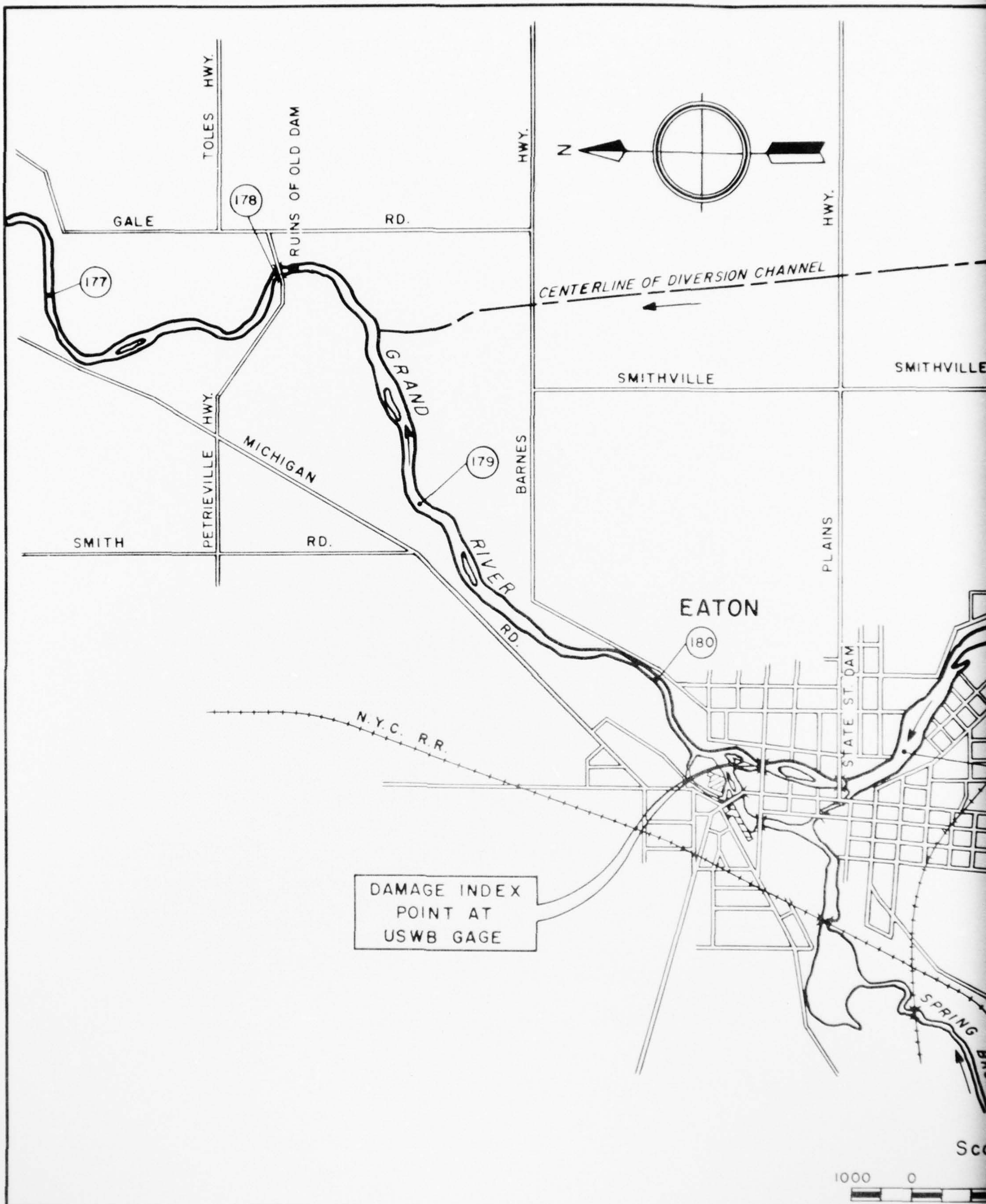


GRAND RIVER BASIN, MICH.
EATON RAPIDS, MICHIGAN

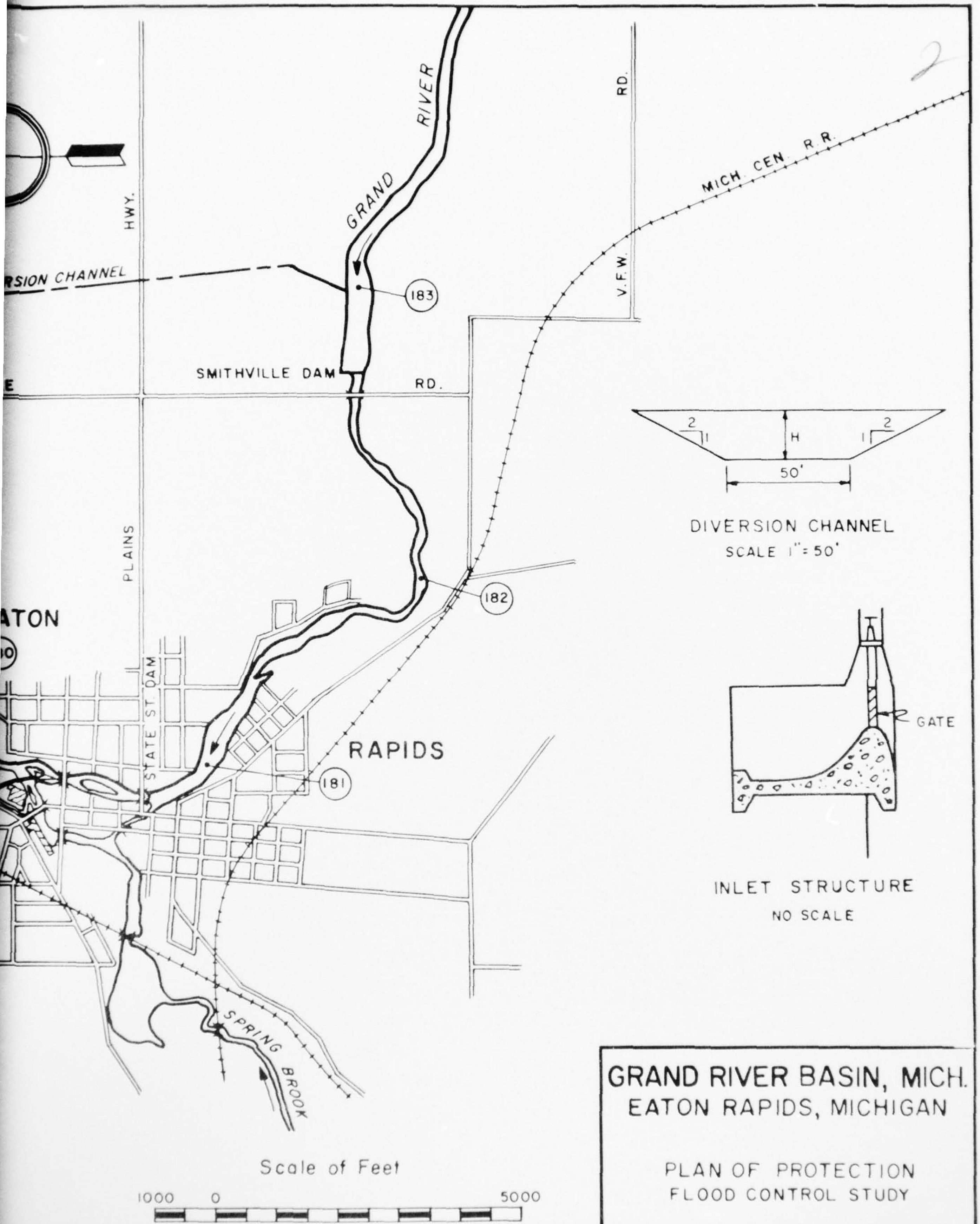
1904 FLOOD OUTLINE

FLOOD CONTROL STUDY

PLATE H-20

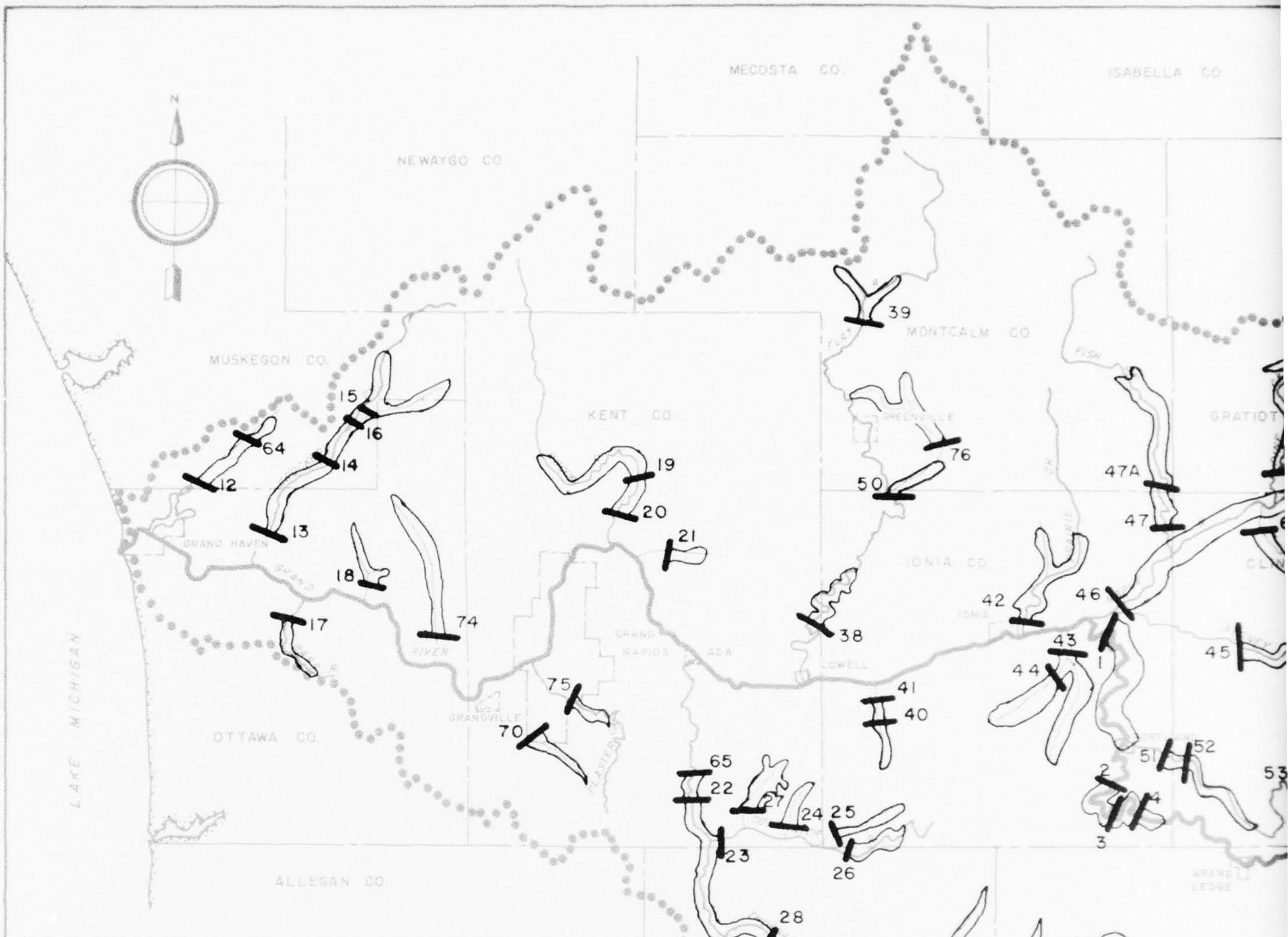


TOLES HWY.
RUINS OF OLD DAM
HWY.
N
178
GALE
RD.
177
HWY.
CENTERLINE OF DIVERSION CHANNEL
GRAND
SMITHVILLE
SMITHVILLE
PETRIEVILLE HWY.
MICHIGAN
179
BARNES
SMITH
RD.
RIVER
PLAINS
RD.
EATON
180
STATE ST. DAM
N.Y.C. R.R.
DAMAGE INDEX POINT AT USWB GAGE
SPRING
Sca
1000
0



GRAND RIVER BASIN, MICH.
EATON RAPIDS, MICHIGAN

PLAN OF PROTECTION
FLOOD CONTROL STUDY



No.	Site Name	No.	Site Name
1	LYONS	27	CAMPBELL LAKE
2	PORTLAND (C.E.)	28	IRVING
3	PORTLAND (MWRC)	29	GLASS CREEK #1
4	DANBY	30	CEDAR CREEK
5	MILLETT	31	NO NAME CREEK
6	DIMONDALE	32	HIGH BANK CREEK
7	ONONDAGA	33	MUD CREEK
8	RIVES JUNCTION	34	SCIPIO CREEK
9	VANDER-COOK LAKE	35	SHANTY BROOK
10	LIBERTY	36	VERMONTVILLE (MWRC)
11	GRAND LAKES	36A	VERMONTVILLE (C.E.)
12	NORRIS CREEK #1	36B	VERMONTVILLE
13	LOWER CROCKERY CR.	37	LACEY CREEK
14	UPPER CROCKERY CR.	38	LOWER FLAT RIVER
15	RAVENNA #1	39	UPPER FLAT RIVER
16	RAVENNA #2	40	LAKE CREEK (WATERVILLE)
17	BASS RIVER	41	LAKE CREEK (SARANAC)
18	DEER CREEK	42	PRAIRIE CREEK
19	ROCKFORD	43	LIBHART CREEK #1
20	CHILDSDALE	44	LIBHART CREEK #2
21	BEAR CR. (CHAUNCEY)	45	STONY CREEK
22	LEBARGE	46	MUIR
23	LOWER COLDWATER	47	FISH CREEK
24	BEAR CR. (FREEPORT)	47A	FISH CREEK
25	DUCK CREEK	48	PINE CREEK
26	FREEPORT	49	ELSIE

No.	Site Name	No.	Site Name
50	DICKERSON CREEK	66	QUAKER BROOK
51	LOOKINGGLASS (MWRC)	67	HAYWORTH CREEK
52	LOOKINGGLASS (C.E.)	68	LITTLE MAPLE RIVER
53	WACOUSTA	69	ALDER CREEK
54	LAINGSBURG	70	BUCK CREEK
55	SYCAMORE CREEK	71	GLASS CREEK #2
56	MUD CREEK	72	SPRING BROOK
57	OKEMOS	73	SMITHVILLE
58	WILLIAMSTON	74	SAND CREEK
59	DOAN CREEK	75	PLASTER CREEK
60	SPRING BROOK #1	76	AMSDEN
61	SPRING BROOK #2		
62	THOMPKIN'S CENTER		
63	PORTAGE LAKE		
64	NORRIS CREEK #2		
65	ALASKA		

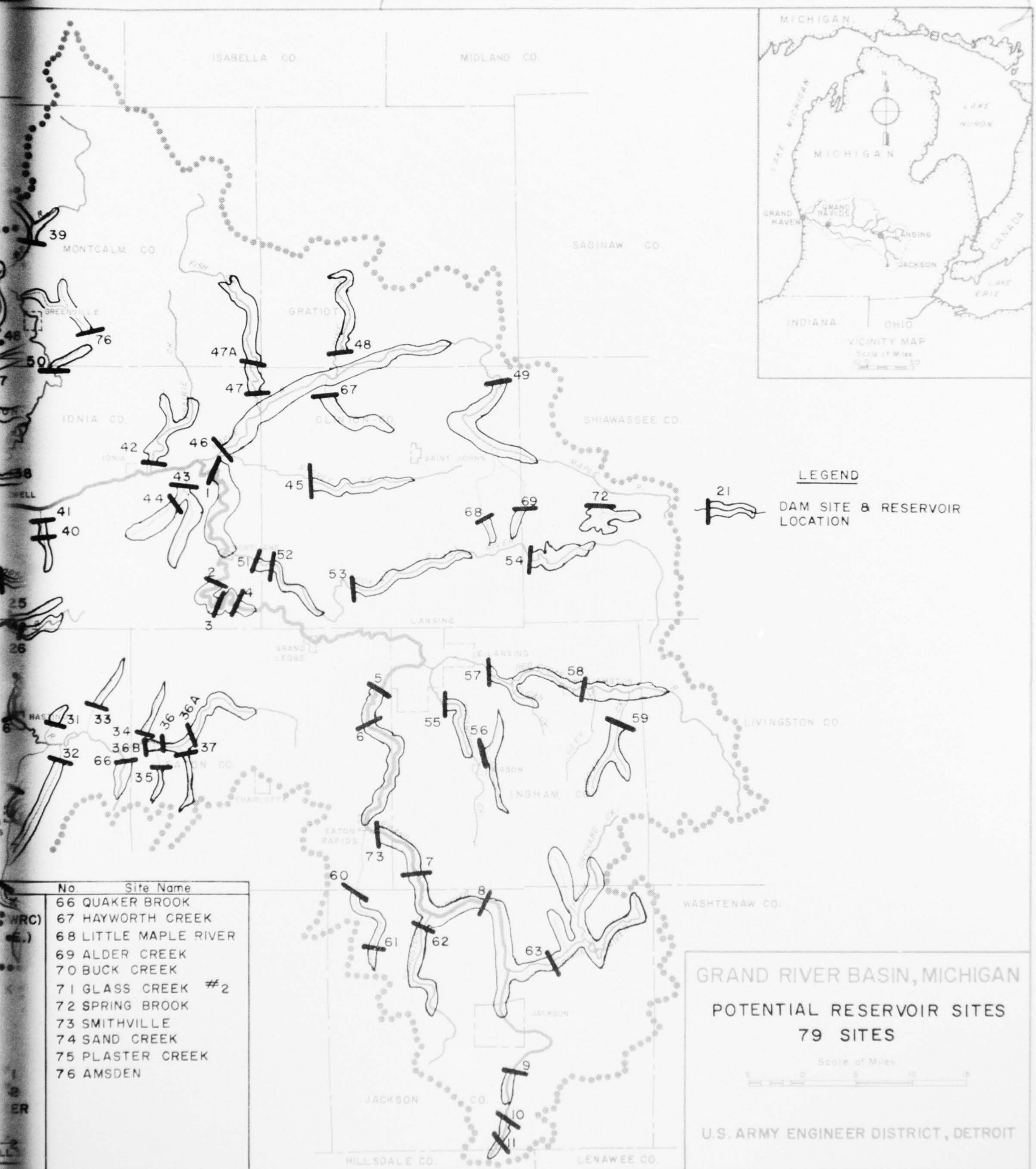

MICHIGAN
LAKE MICHIGAN
LAKE HURON
GRAND HAVEN
GRAND RAPIDS
LANSING
JACKSON
INDIANA
OHIO
CANADA
LAKE ERIE
VICINITY MAP
ISABELLA CO.
MIDLAND CO.
SAGINAW CO.
MONTCALM CO.
GRATIOT
GREENVILLE
IONIA CO.
IONIA
CLINTON CO.
SAINT JOHNS
SHIAWASSEE CO.
LANSING
GRAND LEDGE
EATON CO.
CHARLOTTE
EATON RAPIDS
INGHAM CO.
LIVINGSTON CO.
WASHTENAW CO.
JACKSON
JACKSON CO.
HILLSDALE CO.
LENAWEE CO.
LEGEND
DAM SITE & RESERVOIR LOCATION
No. Site Name
66 QUAKER BROOK
67 HAYWORTH CREEK
68 LITTLE MAPLE RIVER
69 ALDER CREEK
70 BUCK CREEK
71 GLASS CREEK #2
72 SPRING BROOK
73 SMITHVILLE
74 SAND CREEK
75 PLASTER CREEK
76 AMSDEN
GRAND RIVER BASIN, MICHIGAN
POTENTIAL RESERVOIR SITES
79 SITES
Scale of Miles
U.S. ARMY ENGINEER DISTRICT, DETROIT

PLATE H-22

APPENDIX I

NAVIGATION

COMPREHENSIVE PLANNING STUDY
OF THE
GRAND RIVER BASIN, MICHIGAN

Prepared by the
U. S. Army Engineer District, Detroit
Corps of Engineers
Detroit, Michigan

AD-A044 056 GRAND RIVER BASIN COORDINATING COMMITTEE DETROIT MI F/G 8/6
GRAND RIVER BASIN MICHIGAN. COMPREHENSIVE WATER RESOURCES STUDY--ETC(U)
MAY 70

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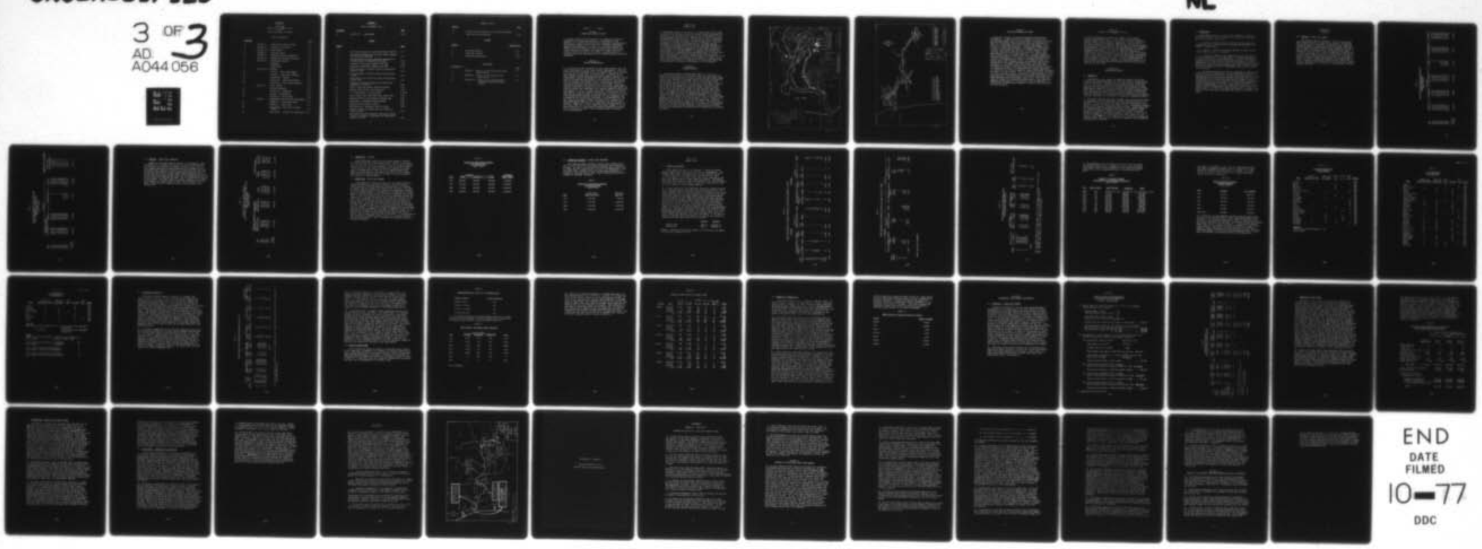
3 OF 3
AD
A044056



END
DATE
FILMED
10-77
DDC

3 OF 3

AD

044056

1.0 2.8 2.5 3.2 2.2 3.6 4.0 2.0 1.1 1.8 1.25 1.4 1.6

MICROCOPY RESOLUTION TEST CHART

NATIONAL BUREAU OF STANDARDS-1963-A

APPENDIX I

NAVIGATION
COMPREHENSIVE PLANNING STUDY
OF THE
GRAND RIVER BASIN, MICHIGAN

TABLE OF CONTENTS

APPENDIX I

TABLE OF CONTENTS (Cont'd)

TABLES

TABLES (Cont'd)

PLATES

ATTACHMENTS

SECTION I
PURPOSE AND EXTENT OF STUDY

1. Various reaches of the Grand River are presently utilized for commercial and recreational navigation. The purpose of this appendix is to identify, within the time framework of the Basin Plan, any imbalance between either existing or foreseeable navigational needs and the adequacy of the river, with or without improvement. Studies include an analysis of existing navigational projects and their relationship to present and prospective commerce and vessel traffic, and the desirability of modifying existing projects or providing additional improvements for both commercial and recreational navigation.

SECTION II
HISTORY OF NAVIGATION

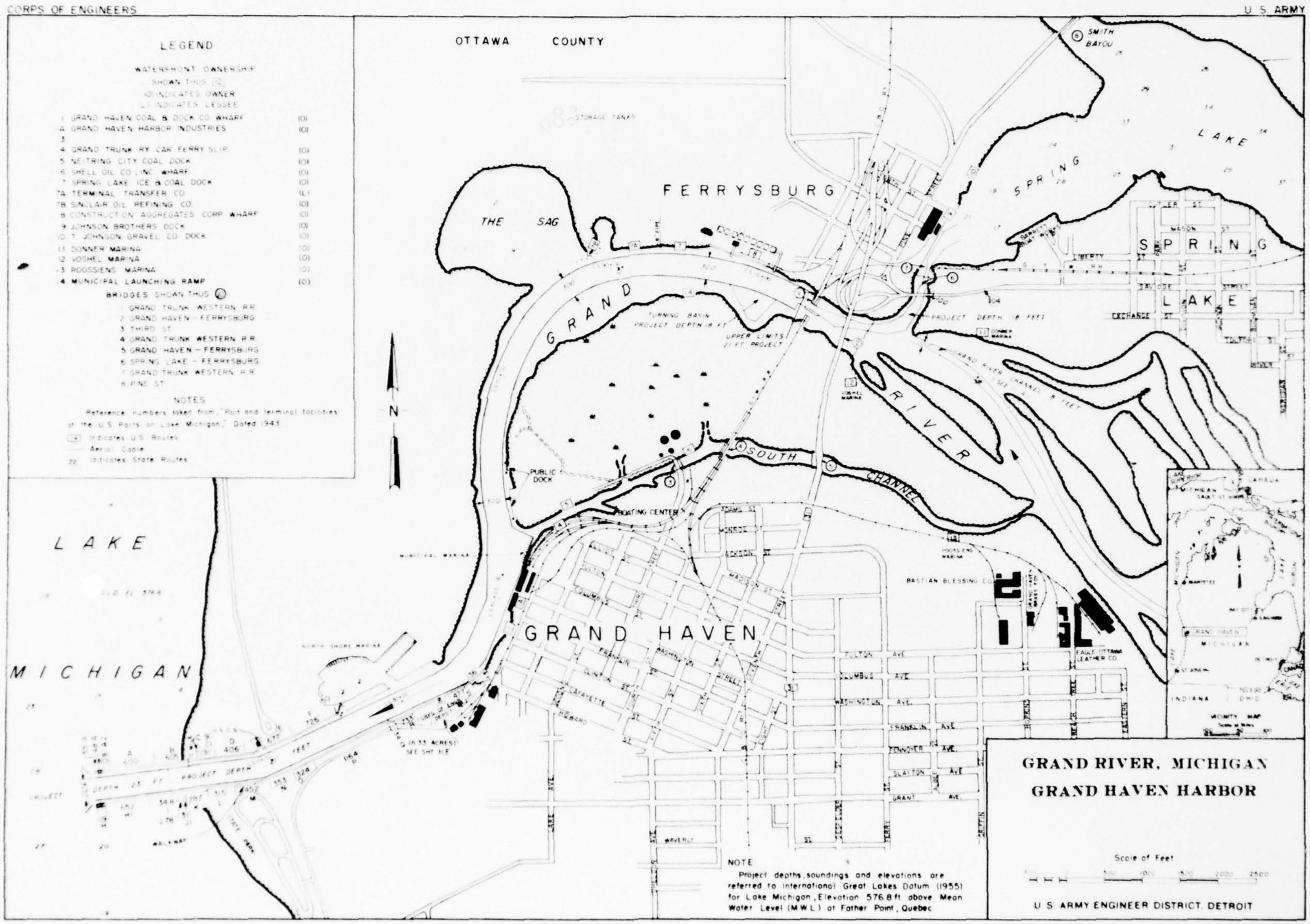
2. The Grand River was navigable for light-draft steamers under high water conditions prior to any known channel improvements. There was a well established steamboat service as early as 1852, which continued with from one to three boats until about 1893. A regular line of boats operated between Lyons and Grand Haven, making a portage at Grand Rapids. Freight and passengers were carried by boat on a regular schedule between Lyons and Chicago. The construction of a lock was begun by the State of Michigan to avoid the portage at Grand Rapids, but its completion was enjoined under a constitutional provision prohibiting the State from being a party to such work. Later operations were confined to the portion of the river below Grand Rapids for carrying supplies and passengers to the numerous sawmills located along that stretch of river. The boats had a draft of about 20 inches and were adapted to the then existing conditions. The river was used extensively for logging purposes up to about 1890. An effort to restore river transportation was made in 1906 and two river steamboats were in operation for the 1906 and 1907 season. The steamboats were 135 feet long, 32 feet wide, and 28 inches draft, with a tonnage of 219 and a passenger allowance of 700. Business did not develop sufficiently to support the line and the boats were sold and removed from the river. From 1911 to 1917, a small side-wheel steamer of 91 net tons and draft of 24 inches operated between Grand Haven and Lamont, 22-1/2 miles above the mouth, and occasionally made an excursion trip to Grand Rapids.

SECTION III
PRIOR REPORTS

3. Grand Haven Harbor at the mouth of the Grand River and the lower 17-1/2 miles of the river are currently under Federal improvement for navigation. The original project for the harbor was adopted by the River and Harbor Act of June 23, 1866 and for the river by the River and Harbor Act of March 3, 1881. There have been numerous modifications to the projects subsequent to these original acts. The River and Harbor Act of July 3, 1930 provided for the present project dimensions of the Grand Haven harbor channel from Lake Michigan to the Grand Trunk Railway car ferry slip, and eliminated that portion of the Grand River channel upstream of the Bass River extending to Grand Rapids. It also consolidated the separate projects for the harbor and river. Subsequent River and Harbor Acts, in 1937 and 1945, authorized the channel extension to Spring Lake and the present project dimensions of the harbor channel from the car ferry slip to the Grand Trunk Railway Bridge and the turning basin. A summary of the prior reports pertaining to navigation on the Grand River downstream of Grand Rapids is contained in Attachment A to this appendix.

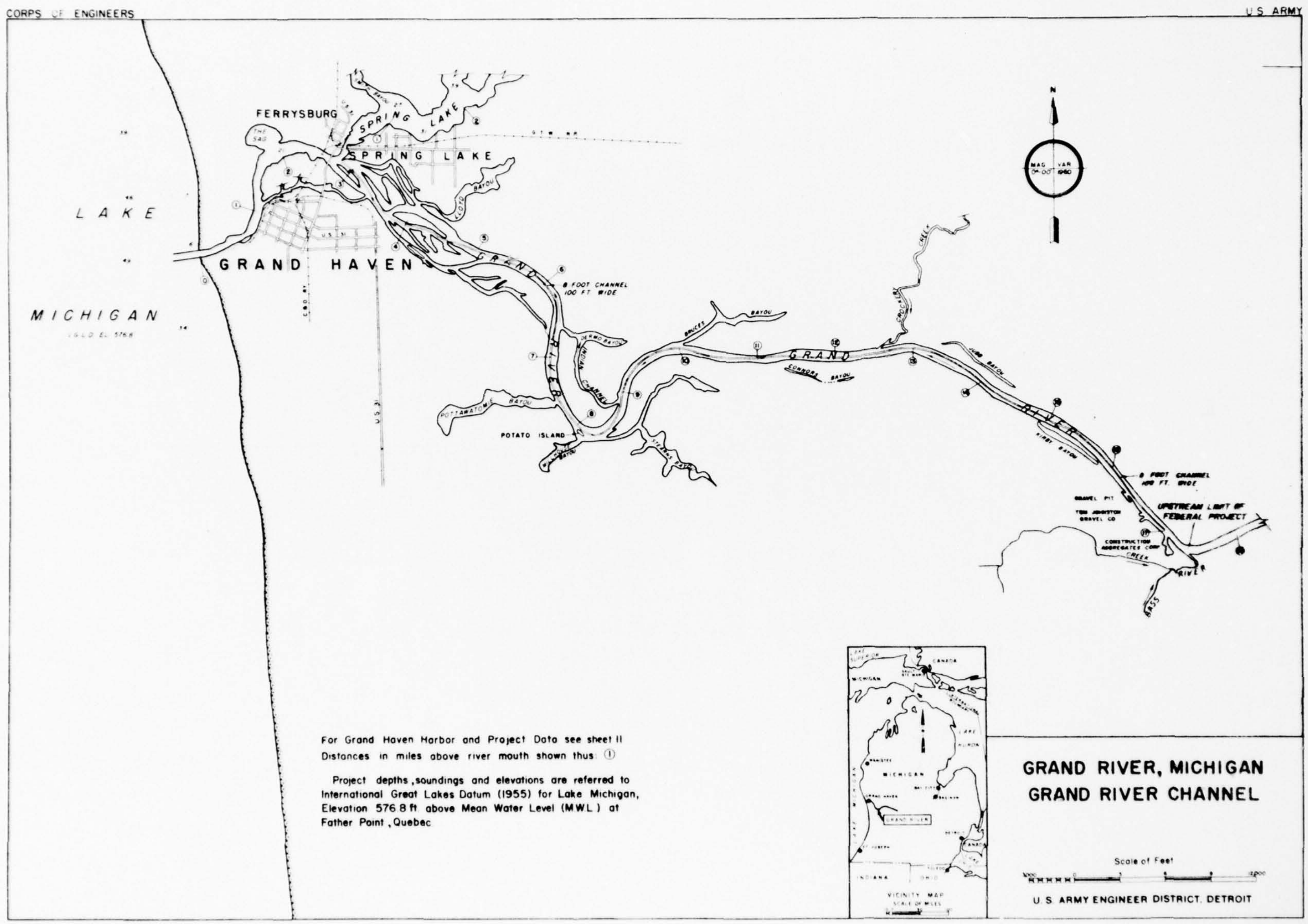
SECTION IV
EXISTING PROJECT

4. The existing project for Grand Haven Harbor and Grand River provides for protecting the mouth of the river with piers and revetments, 3,569 and 5,549 feet in length on north and south sides, respectively; for a channel 23 feet deep, 300 feet wide from that depth in Lake Michigan to a point 1,000 feet inside the pier ends; thence 21 feet deep, 300 feet wide, 2-1/2 miles long to the Grand Trunk Railway Bridge at Ferrysburg with a turning basin 18 feet deep on the south side of the channel just below the bridge; thence a channel 18 feet deep, 100 feet wide, 3,100 feet long to Spring Lake; and a channel in Grand River 8 feet deep, 100 feet wide and 14-1/2 miles long. The existing project was substantially completed in 1949. A controlling depth of 23 feet is presently available in the entrance channel; 21 feet between the piers and in the river to the Grand Trunk Railway Bridge; 18 feet in the turning basin; 8 feet in Grand River to Bass River; and 18 feet in the outlet from Spring Lake. Existing project layouts are shown on maps, plates 1 and 2. All project structures are in generally good condition. Total costs of the navigation projects to 30 June 1969 have amounted to $1,283,469 for new work, $6,462,267 for maintenance, and $813,613 for rehabilitation of project structures.



CORPS OF ENGINEERS
U.S. ARMY
LEGEND
WATERFRONT OWNERSHIP
SHOWN THUS [12]
(O) INDICATES OWNER
(L) INDICATES LESSEE
1 GRAND HAVEN COAL & DOCK CO WHARF (O)
1A GRAND HAVEN HARBOR INDUSTRIES (O)
3
4 GRAND TRUNK RY. CAR FERRY SLIP (O)
5 NEITRING CITY COAL DOCK (O)
6 SHELL OIL CO., INC. WHARF (O)
7 SPRING LAKE ICE & COAL DOCK (O)
7A TERMINAL TRANSFER CO. (L)
7B SINCLAIR OIL REFINING CO. (O)
8 CONSTRUCTION AGGREGATES CORP. WHARF (O)
9 JOHNSON BROTHERS DOCK (O)
10 T. JOHNSON GRAVEL CO. DOCK (O)
11 DONNER MARINA (O)
12 VOSHEL MARINA (O)
13 ROOSSIENS MARINA (O)
14 MUNICIPAL LAUNCHING RAMP (O)
BRIDGES SHOWN THUS
1 GRAND TRUNK WESTERN R.R.
2 GRAND HAVEN — FERRYSBURG
3 THIRD ST.
4 GRAND TRUNK WESTERN R.R.
5 GRAND HAVEN — FERRYSBURG
6 SPRING LAKE — FERRYSBURG
7 GRAND TRUNK WESTERN R.R.
8 PINE ST.
NOTES
Reference numbers taken from "Port and terminal facilities at the U.S. Ports on Lake Michigan," Dated 1943
Indicates U.S. Routes
Aerial Cable
Indicates State Routes
OTTAWA COUNTY
STORAGE TANKS
FERRYSBURG
THE SAG
SMITH BAYOU
SPRING LAKE
SPRING LAKE
GRAND RIVER
TURNING BASIN PROJECT DEPTH 18 FT
UPPER LIMITS 21 FT PROJECT
PROJECT DEPTH 18 FEET
GRAND RIVER CHANNEL 8 FEET
SOUTH CHANNEL
PUBLIC DOCK
BOATING CENTER
MUNICIPAL MARINA
NORTH SHORE MARINA
BASTIAN BLESSING CO.
EAGLE OTTAWA LEATHER CO.
LAKE MICHIGAN
GRAND HAVEN
PROJECT DEPTH 21 FEET
PROJECT DEPTH 23 FT
N
NOTE
Project depths, soundings and elevations are referred to International Great Lakes Datum (1955) for Lake Michigan, Elevation 576.8 ft. above Mean Water Level (M.W.L.) at Father Point, Quebec
GRAND RIVER, MICHIGAN
GRAND HAVEN HARBOR
Scale of Feet
500 0 500 1000 1500 2000 2500
U.S. ARMY ENGINEER DISTRICT, DETROIT

PLATE I-1


CORPS OF ENGINEERS
U.S. ARMY
LAKE
MICHIGAN
FERRYSBURG
SPRING LAKE
GRAND HAVEN
GRAND RIVER
8 FOOT CHANNEL 100 FT. WIDE
POTATO ISLAND
UPSTREAM LIMIT OF FEDERAL PROJECT
For Grand Haven Harbor and Project Data see sheet II
Distances in miles above river mouth shown thus: (1)
Project depths, soundings and elevations are referred to International Great Lakes Datum (1955) for Lake Michigan, Elevation 576.8 ft above Mean Water Level (MWL) at Father Point, Quebec
VICINITY MAP
GRAND RIVER, MICHIGAN
GRAND RIVER CHANNEL
Scale of Feet
U.S. ARMY ENGINEER DISTRICT, DETROIT

SECTION V
ADDITIONAL STUDIES AUTHORIZED

5. There are currently two authorized studies concerning the modification of existing projects or adoption of new projects at Grand Haven Harbor and on the Grand River. One study, in accordance with House Public Works Committee Resolution dated March 1, 1950, is to investigate the need for further improvements in the interest of commercial navigation. Although the original intent of local interests was to consider the advisability of improving a branch of the Grand River known as the "South Channel", local interests subsequently modified their request to include other improvements in lieu of the South Channel. At a public hearing held in Grand Haven on 26 March 1968, local interests proposed the following improvements: (1) deepen the existing deep-draft harbor channel to a minimum depth of 25 feet; (2) deepen and widen the turning basin; and (3) deepen, widen, and straighten the existing shallow-draft river channel from Grand Haven to the Bass River. Improvement of the harbor channel and turning basin will permit utilization of larger, modern lake vessels with a resultant savings in transportation costs. The requested river channel improvement will allow the use of larger barges and larger tows thereby decreasing the number of trips required. Work on this study has been initiated. The other authorized study is to determine if any modification of the existing project is advisable and is in accordance with House Public Works Committee resolution adopted 9 April 1957. This study will cover all aspects of recreational boating activity, with particular emphasis on improvement of the Grand River from the Bass River to Grand Rapids for small-craft navigation. Work on this study has not yet been initiated.

SECTION VI
TERMINAL AND TRANSFER FACILITIES

6. The only significant terminal and transfer facilities are located at Grand Haven Harbor. They consist of several wharves used for handling coal, limestone, slag, sand and gravel, petroleum products, fish, and miscellaneous commodities. There is also a car ferry slip which is inactive. Sand and gravel shipping terminals are located near the Bass River at the upstream limit of the existing Federal project. Sand and gravel from these terminals are shipped by barge to Grand Haven. There are no commercial terminals or transfer facilities located at the city of Grand Rapids. For recreational craft, there are marinas in the Grand Haven area and numerous landing places along the river. These facilities appear adequate for existing commerce and vessel traffic. If channel improvements are made to permit a significant increase in recreational boating, it is expected that additional marinas and boating facilities will be provided as the need arises.

SECTION VII
IMPROVEMENTS DESIRED

7. COMMERCIAL

Improvements in the interest of commercial navigation have been requested for Grand Haven Harbor and the lower reach of the Grand River up to the Bass River. Deepening of the existing harbor channel from 21 feet to 25 feet and enlarging and deepening the existing turning basin are improvements which local interests have requested for Grand Haven Harbor. According to local interests, the existing project depth of 21 feet prevents the realization of more economical transportation rates available from loading larger, deep-draft vessels to their full capacity. Enlarging the turning basin would provide additional maneuvering space and permit the utilization of larger more economical vessels.

8. Two gravel companies operating in Ottawa County have requested widening and deepening of the Grand River over the existing project up to the mouth of the Bass River. They state that these improvements would permit an increase in transporting capacity with a corresponding economic savings in the movement of sand and gravel by barge. Larger barges and an increased number of barges per tow would then be possible should the channel be improved. Widening the channel would also increase safety to navigation, especially at bends of the river, in view of the increasing commercial and recreational boat traffic expected in the future. These companies stated that they see no need for extending the improved channel upstream of the Bass River insofar as their commercial applications are concerned.

9. RECREATIONAL

The Waterways Division of the Michigan Department of Natural Resources requested that the following improvements be investigated as to their economic feasibility.

a. Construct a channel 100 feet wide and five feet deep from the upstream limit of the presently authorized and maintained river channel to Grand Rapids.

b. Construct a lock at Grand Rapids adequate to handle recreational craft up to 65 feet in length.

c. Construct a channel 80 feet wide and five feet deep from the site of the proposed lock at Grand Rapids to a point approximately 70 miles from the mouth of the Grand River, at Lowell, and construct a channel 50 feet wide and four feet deep from Lowell, to a point approximately 110 miles from the mouth of the Grand River, at Portland. Where active dams are encountered along this route, provision should be made for portages, except at Grand Rapids, where a lock is deemed to be essential.

d. Provide additional water areas by impounding the waters of the Grand River and its tributaries in at least two areas; one between Lansing and Portland and the other between Lansing and Jackson. These impoundments would be intended to provide recreational water areas for the residents of the Lansing area and should be designed to permit recreational boating. Each impoundment should provide a minimum water surface acreage of about 650 acres. It is considered desirable to plan such impoundments so that the minimum width of the lake created thereby would be approximately 2,000 feet and a minimum length of the lake one mile. If a lake of 650 acres was provided, a minimum of four miles of shore line would be available per lake for recreational purposes.

SECTION VIII
COMMERCE

10. EXISTING - GRAND HAVEN HARBOR

The volume of lakewise waterborne commerce through Grand Haven Harbor amounted to 1,682,837 tons in 1967. The greater portion was moved by deep-draft self-unloader type vessels and consisted largely of coal, slag, petroleum products, and limestone receipts along with sand and gravel shipments. During the past 10 years, the commerce of the harbor has varied from a minimum of 1,222,707 tons in 1964 to a maximum of 1,682,837 tons in 1967, the average of the 10-year period, 1958 to 1967 being 1,467,025 tons. Table 1 details the tonnages of the primary commodities received by lake vessels during this 10-year period. Table 2 details the commodities shipped by lake vessels and the total of shipments and receipts for this 10-year period. Miscellaneous commodities have included salt, slag, gypsum, steel mill products, and fish.

Table 1

Lake Vessel Receipts at Grand Haven
1958 through 1967
(Short Tons)

Year	Receipts					
	Coal	Limestone	Petroleum	Slag	Miscellaneous	Total
1958	66,777	89,911	422,397	0	7,948	587,033
1959	51,717	42,590	425,383	0	17,489	537,179
1960	48,370	71,415	424,369	0	13,999	558,153
1961	83,750	156,370	449,571	0	54,692	744,383
1962	86,418	112,899	469,919	0	24,160	693,396
1963	76,139	69,486	259,597	49,633	14,699	469,554
1964	65,475	59,900	254,456	27,413	25,674	432,918
1965	68,572	40,902	285,996	47,576	41,095	484,141
1966	109,244	53,704	264,754	51,080	47,424	526,206
1967	123,835	82,708	257,234	51,710	44,995	560,482
10-Year Average	78,030	77,989	351,368	22,740	29,218	559,345

Table 2

Lake Vessel Shipments and Total Lake Vessel Commerce at Grand Haven 1958 through 1967 (Short Tons)

	Shipments				Shipments and Receipts
	Sand and Gravel				
Year	U. S. Ports	Export	Miscellaneous	Total	Total Lake Vessel Commerce
1958	592,538	189,669	0	782,207	1,369,240
1959	908,722	230,705	0	1,139,427	1,676,606
1960	801,947	166,918	0	968,865	1,527,018
1961	455,041	147,891	0	602,932	1,347,315
1962	546,409	203,985	0	750,394	1,443,790
1963	659,991	135,592	0	795,583	1,265,137
1964	571,943	217,846	0	789,789	1,222,707
1965	665,109	268,412	115,013	1,048,534	1,532,642
1966	672,741	386,081	17,933	1,076,755	1,602,961
1967	752,061	331,001	39,293	1,122,355	1,682,837
10-Year Average	662,650	227,810	17,224	907,684	1,467,025

11. <u>EXISTING</u> - GRAND RIVER INTRAPORT

Commerce on the Grand River is limited to the shipment of sand and gravel from the deposits located at the mouth of the Bass River to the Harbor at Grand Haven, a distance of 14-1/2 miles. All of this commerce was moved by shallow-draft barges, two barges per tow, and during 1968 consisted of 728,594 tons of sand from the area known as "The Sag" and 1,060,160 tons of unprocessed gravel from the reserves near the mouth of the Bass River. After processing the gravel, 373,119 tons were shipped by lake vessel and the remaining 687,041 tons were distributed by railroad and truck. All of the sand was reshipped by lake vessel. The total volume of intraport commerce on the Grand River amounted to 1,788,754 tons in 1968. Table 3 details the tonnages of sand and gravel commerce during the 5-year period, 1964 through 1968.

Table 3

Intraport Sand and Gravel Shipments
and Method of Redistribution at Grand Haven
1964 through 1968
(Short Tons)

	Intraport Shipments and Receipts			Redistributing	
Year	Gravel from Bass River Area	Sand from "the Sag" area	Total	Lake Vessel	Railroad and Truck
1964	681,807	468,508	1,150,315	789,789	360,526
1965	822,040	614,946	1,436,986	1,048,534	388,452
1966	997,998	732,568	1,730,566	1,076,755	653,811
1967	1,036,173	640,473	1,676,646	1,122,355	554,291
1968	1,060,160	728,594	1,788,754	1,101,713	687,041
5-Year Average	919,636	637,018	1,556,654	1,027,829	528,824

12. PROSPECTIVE - GENERAL

Future waterborne commerce at Grand Haven Harbor is expected to increase along with an anticipated steady increase in population over the tributary area and future growth in road building, building construction, and industrial expansion. Growth of general industry is expected due to the harbor's geographical location on the west coast of Michigan and its proximity to the industrialized Grand Rapids Metropolitan Area. The expected increase in vessel commerce will continue to consist mainly of receipts of coal and limestone and shipments of sand and gravel.

13. PROSPECTIVE - GRAND HAVEN HARBOR

Local commercial interests indicate that the harbor's sand and gravel shipments can be expected to increase. Several reserves presently serving the Great Lakes are near depletion. An increase of 500,000 tons by the year 1975 is expected as the bulk of the sand and gravel presently shipped from reserves near depletion is absorbed by the Grand Haven Harbor. The shipments can be expected to increase annually by about 25,000 tons per year during the period 1975 through 1985. It was also indicated that the harbor's limestone receipts can be expected to increase annually by about 5,000 tons through the year 1985. Coal, primarily that used in the production of electricity, can be expected to increase by 108,000 tons by 1970, an additional 237,000 tons by 1975, and 1,600 tons annually from 1975 through 1985. The Board of Light and Power of the City of Grand Haven has indicated that the capacity of their Island Generating Station will be increased from the present 20 megawatts to 50 and 110 megawatts by 1970 and 1975 respectively, requiring a large increase in their coal usage. It is expected that by 1985, annual inbound vessel traffic will include 485,000 tons of coal and 183,000 tons of limestone. It is also expected that outbound self-unloading vessel traffic will include 2,000,000 tons of sand and gravel. Table 4 indicates the projected tonnages in five-year increments.

Table 4

Prospective Lake Vessel Commerce
1970 through 1985
(Short Tons)

Year	RECEIPTS Coal	Limestone	Total	SHIPMENTS Sand, Gravel
1970	232,000	108,000	340,000	1,430,000
1975	469,000	133,000	602,000	1,770,000
1980	477,000	158,000	635,000	1,870,000
1885	485,000	180,000	665,000	2,000,000

14. PROSPECTIVE COMMERCE - GRAND RIVER INTRAPORT

Local sand and gravel interests indicate that intraport shipments to their processing and shipping facilities can be expected to increase. By 1985, it is expected that 2,000,000 tons of gravel will be shipped from the reserves near the mouth of the Bass River to the processing plant. Foundry sand from the Sag Area is expected to increase to 1,397,000 tons by 1985. Table 5 indicates the projected tonnages in five-year increments.

Table 5

Prospective Grand River Commerce
1970 through 1985
(Short Tons)

Year	Gravel from Bass River Area	Sand from Sag Area
1970	1,251,000	943,000
1975	1,440,000	1,268,000
1980	1,703,000	1,336,000
1985	2,000,000	1,397,000

SECTION IX
VESSEL TRAFFIC

15. EXISTING COMMERCIAL

Great Lakes bulk cargo is transported by a fleet of vessels which is undergoing a gradual, but deliberate, transformation. The average draft, length, and capacity of the lake carriers is continually increasing. Two factors have accelerated this trend: (1) obsolescence in the present fleet; and (2) the deepening of the Connecting Channels and the major commercial harbors. New vessels, which have been designed to take full advantage of the greater depths, and vessels that have been rebuilt, operate at a lower cost per ton only when loaded at or near maximum capacity.

16. Vessel traffic data for Grand Haven Harbor were tabulated according to trips and drafts during 1967 and are shown in table 6. The latest available data for the Grand River are presented in table 7 and shows trips and drafts of vessels trading on the Grand River in 1964. Inbound and outbound deep-draft vessels serving Grand Haven Harbor consist primarily of Great Lakes self-unloader bulk cargo carriers (see table 8) and tankers. Tugs and barges handling sand and gravel comprise most of the shallow-draft vessel traffic at Grand Haven Harbor and on the Grand River. The largest barges presently being utilized are 175 feet long and 40 feet wide with a loaded draft of between 7 to 8 feet. The carrying capacity per barge is approximately 1,200 tons. The largest tow used at the present time consists of two barges and a push tug which amounts to an overall length of 410 feet. The navigation season on the Grand River normally starts about the first of April and ends about the first of December. In the past ten years, the earliest and latest dates for the opening and closing of navigation at Grand Haven Harbor are as follows:

	Opening	Closing
Earliest date	March 4	November 11
Latest date	April 7	December 29

However, local fish tugs and oil tankers ply in and out of the harbor at all times throughout the year.

Table 6

Trips and Drafts of Vessels Trading at Grand Haven Harbor in 1967

Draft (feet)	Inbound: Self-propelled vessels: Passenger and dry cargo	Inbound: Self-propelled vessels: Tanker	Inbound: Self-propelled vessels: Towboat or tugboat	Inbound: Non-self-propelled vessels: Dry cargo	Inbound: Non-self-propelled vessels: Tanker	Inbound: Total	Outbound: Self-propelled vessels: Passenger and dry cargo	Outbound: Self-propelled vessels: Tanker	Outbound: Self-propelled vessels: Towboat or tugboat	Outbound: Non-self-propelled vessels: Dry cargo	Outbound: Non-self-propelled vessels: Tanker	Outbound: Total
22	1	-	-	-	-	1	23	-	-	-	-	23
21	9	-	-	-	-	9	63	-	-	-	-	63
20	9	3	-	5	-	17	35	1	-	4	-	40
19	7	10	-	-	-	17	4	-	-	-	-	4
18	13	4	-	-	-	17	1	-	-	-	-	1
17	30	18	-	-	-	48	9	-	-	-	-	9
16	38	12	-	-	-	50	2	9	-	-	-	11
15	20	2	-	-	-	22	11	4	-	-	-	15
14	1	1	-	-	-	2	-	11	-	-	-	11
13	-	5	9	-	-	14	-	3	9	-	-	12
12 & less	22	4	1,327	1,837	3	3,193	2	31	1,326	1,838	3	3,200
Total	150	59	1,336	1,842	3	3,390	150	59	1,335	1,842	3	3,389

Table 7

Trips and Drafts of Vessels Trading on Grand River in 1964 *

	Inbound			Outbound		
	Self-propelled vessels	Non-self-propelled vessels	Total	Self-propelled vessels	Non-self-propelled vessels	Total
Draft (feet)	Towboat or tugboat	Dry cargo		Towboat or tugboat	Dry cargo	
9	-	-	-	-	261	261
8	-	-	-	-	531	531
7	-	-	-	-	706	706
6	224	-	224	224	215	439
5	1,071	-	1,071	1,071	-	1,071
2	-	1,713	1,713	-	-	-
Total	1,295	1,713	3,008	1,295	1,713	3,008

* Last year data available.

Table 8

United States Great Lakes Bulk Cargo
Self-Unloader Vessel Fleet

Class	Overall Length feet	Coal Cargo Draft feet (1)	Coal Cargo Capacity tons	Other Cargo (2) Draft feet	Other Cargo (2) Capacity tons	1967 Fleet	1968 Fleet	1967 calls @ Grand Haven (3)
1	Under 400	-	-	-	-	6	1	1
2	400-499	-	-	-	-	10	4	17
3	500-549	20.5	10,300	21.0	11,800	10	9	51
4	550-599	20.0	12,400	21.8	14,000	13	13	46
5	600-649	22.1	17,100	23.6	20,100	8	12	26
6	650-699	23.0	18,200	25.3	22,300	1	4	-
7	Over 699	23.0	20,100	25.4	24,700	-	-	-
Totals						48	41	141

(1) The maximum draft for a coal cargo, due to its bulkiness, is assumed to be 23.0 feet.
(2) Applicable for vessel traffic that does not involve Lake Superior.
(3) Includes calls made by vessels of Canadian registration.

17. Self-unloading and bulk carriers have shipped sand and gravel from Ferrysburg for delivery throughout the Great Lakes system for forty years. Table 9 gives a summary of boats loaded and outbound tonnages from a local commercial interest, during 1948 and 1957 - 1967.

Table 9

A Summary of Outbound Tonnage
From Construction Aggregates Corporation
(Short Tons)

Year	Boats Loaded	Lake Michigan	Downbound	Total
1948	156	538,521 net tons	378,531 net tons	917,052 net tons
1957	137	453,647	639,466	1,093,113
1958	91	341,280	453,409	794,689
1959	129	456,148	683,311	1,139,459
1960	117	437,122	527,177	964,299
1961	73	269,635	378,618	648,253
1962	95	263,650	492,473	756,123
1963	101	436,336	484,022	920,358
1964	99	222,780	585,787	808,567
1965	112	295,761	657,598	953,359
1966	118	382,192	760,572	1,142,764
1967	112	483,304	628,313	1,111,617

18. Table 10, furnished by local interest, shows sales of sand and gravel to Canadian consumers. Up to 40 percent of the sand and gravel shipments from Grand Haven go to Canada. The result being a return of American dollars to the economy which helps control the balance of payments.

Table 10

Sales of Sands and Gravels
Canadian Consumers
(Short Tons)

Year	Tonnage	U. S. Dollars
1963	261,519	$168,196
1964	236,630	185,333
1965	281,186	214,366
1966	442,644	351,983
1967	319,605	265,373
1968 (Est.)	405,000	362,000

19. A study of U. S. and Canadian flag self-unloading vessels shows that most of the vessels calling at Grand Haven had attanable drafts of over 21', the limiting project depth. Tables 11 and 12 were furnished by a local commercial interest. These tables indicate many vessels were unable to fill to, or near capacity. The vessels with maximum drafts less than 21' probably will soon be replaced with deeper draft, longer vessels. With ships calling at Grand Haven not loading to capacity, economic advantages of cheaper shipping are lost. Deepening Grand Haven Harbor to Great Lakes Connecting Channels depths is necessary to accommodate the existing and future Great Lakes fleet.

Table 11

Canadian Flag Vessels
Self-Unloaders

Boat	Number of Calls at GH 1967	Called at GH in past	Under 21'	21'-23'	Over 23'	Length
Avondale			X			489
Barber	3				X	574
Bayfair			X			258
Baygeorge			X			343
Codwell			X			162
Cape Breton Miner					X	680
Dolomite	1	X				425
Everest			X			259
Ferndale			X			524
Gleneagles		X		X		596
Ballfax					X	445
Hochelaga					X	639
Hull					X	730
Jodrey	2				X	641
Leadale		X	X			524
Manitoulin					X	730
Midland Prince				X		484
Ontario Power					X	710
Orefax	1	X				341
Petman		X		X		510
Pinedale		X		X		524
Stadacona				X		596
Stonefax	3	X	X			441
Tarantau					X	730

LOAD-OUT

Total Trips by Self-Unloaders -- 10

Total Vessels 5

Table 12

U. S. Flag Vessels
Self-Unloaders

Boat	Number of Calls at GH 1967	Called at GH in Past	Under 21'	21'-23'	Over 23'	Length
Alpena			X			376
Boland, J. J.					X	639
Calcite II	8	X		X		604
Calvin		X	X			557
Clyner		X		X		552
Consumers Power				X		605
Cornelius					X	666
Detroit Edison					X	678
Diamond Alkali	2	X		X		600
Fitzgerald	1	X	X			440
Frantz	3	X		X		618
Hennepin	8	X		X		524
Holloway		X		X		552
Huron		X		X		439
Hutchinson					X	620
Kling	8	X		X		561
Manske		X	X			524
McKee Sons	2				X	633
Munson					X	666
Nicolet	14	X		X		533
Norton		X		X		524
Oglebay	27	X		X		556
Purnell	4	X			X	620
Reiss, C.	7	X		X		524
Reiss, J. L.	6	X		X		500
Reiss, P.	14	X		X		524
Reiss, R. J.					X	620
Robinson				X		588
Rogers City	2	X		X		552
Schoellkopf		X		X		557
Sensibar	5	X		X		610
Sloan					X	620
Snyder	1	X	X			526
Sylvania	1	X	X			572

U. S. Flag Vessels
Self-Unloaders

Boat	Number of Calls at GH 1967	Called at GH in Past	Under 21'	21'-23'	Over 23'	Length
Taylor				X		603
Thompson	2	X		X		579
Tomlinson	1	X		X		557
U. S. Gypsum	1	X	X			524
West	2	X		X		592
White				X		550
Wyandotte	4	X		X		439
Young					X	672
Roen	8	X		X		461

LOAD-OUT
Total trips by Self-Unloaders 1967 -- 96 from Construction Aggregates Corporation
by Barges 6 from Construction Aggregates Corporation

UNLOAD
Total trips by self-unloaders to Board of Light & Power -- 7
Total vessels to Board of Light & Power -- 1

Total trips by self-unloaders to Verplanks 18
Total vessels to Verplanks 4

Total trips to Construction Aggregates 5
Total vessels to Construction Aggregates 4

Total trips to Neitring's City Coal Dock 2
Total vessels to Neitring's City Coal Dock 2

20. PROSPECTIVE COMMERCIAL

Grand Haven Harbor's commerce is expected to increase, and consist mainly of receipts of coal, limestone, and sand and gravel. Land and dock sites along the shore, rail facilities, highways, and an improved deep-draft harbor serve as an incentive to attract new industry and waterborne commerce. It is expected that the size of deep-draft vessels serving Grand Haven Harbor will increase in the future. The average size of vessels in the Great Lakes bulk cargo fleet has been increasing since World War II and more noticeably in the last ten years. This increase is attributed to the fact that many of the smaller vessels have reached or passed their 50-year life expectancy and greater economies are realized by using larger, more efficient carriers. Completion of the St. Lawrence Seaway and deepening of the Great Lakes Connecting Channels, together with the deepening of major commercial harbors, have served to accelerate this transition. Most new vessels, which have been designed to take advantage of the greater depths now available, operate at a lower cost per ton only when loaded at or near maximum capacity.

21. The probable composition of the 1985 Great Lakes bulk cargo fleet, with Connecting Channels and principal harbors deepened, was developed for the Great Lakes Connecting Channels Report (S. Doc. No. 71, 84th Cong., 1st Sess.). Based on more recent studies certain changes have been made in the characteristics of the prospective fleet. Table 13 presents the results of this prospective fleet study together with comparative characteristics of the 1957 and 1965 fleets. Special-use types of bulk carriers such as cement carriers and tankers are not included in Table 13. Future traffic at Grand Haven Harbor will consist of the larger deeper-draft vessels of the current fleet plus new vessels of at least a comparable size.

Table 13

United States Great Lakes Bulk Cargo Vessel Fleet

Class	Overall length feet	Bulk Carriers		Self-unloading		1957 fleet		1965 fleet		Prospective (1985) fleet	
		Draft feet (1)	Capacity tons (1)	Draft feet (1)	Capacity tons (1)	Bulk Carriers	Self-unloaders	Bulk Carriers	Self-unloaders	Bulk Carriers	Self-unloaders
1	Under 400	-	-	-	-	1	6	0	0	0	0
2	400 - 499	21.0	10,000	-	-	35	10	4	3	2	0
3	500 - 549	21.3	12,900	22.2	11,800	53	10	16	9	5	3
4	550 - 599	21.9	15,500	21.7	14,000	45	13	15	13	28	6
5	600 - 649	25.0	22,100	25.6	20,200	107	8	96	11	55	3
6	650 - 699	25.7	23,300	25.8	22,400	3	1	8	4	58	7
7	Over 700	26.5	28,000	26.2	24,900	4	0	12	-	26	2
					Total	248	48	151	40	174	21

(1) Draft and capacity of vessels pertain to summer season. Capacities indicated are considered applicable to prospective fleet.

22. It is expected that self-unloaders will continue to carry the harbor's bulk coal, limestone, sand, and gravel commerce. The large tonnage increases expected for these commodities in the future will result in increased harbor traffic, and the need for deeper harbor facilities, to accommodate deep-draft shipping. Shipping companies on the Great Lakes have been retiring or rebuilding their old, small, and inefficient ships at an ever increasing rate. The composition of the fleet of self-unloaders serving the Great Lakes is expected to change during the proposed improvements 50-year amortization period.

23. On the Grand River, the present channel dimensions directly limit the size (width, length, and draft) of the barges used in the movement of sand and gravel. Present tows consist of a maximum of two barges; however, the principal shipping company operating on the Grand River is considering the use of three barges and a tug bringing the over-all length per tow to 585 feet. These longer tows will be able to operate only during periods of high water inasmuch as at other times the longer tows will not be able to make the short bends of the river. The 100-foot width of the present channel does not permit a tow of this length to navigate the sharp turns and still remain within the channel lines. Commercial interests have stated that if the channel dimensions were enlarged, they would definitely increase the size of their barges and tows. Thus, the nature of future commercial vessel traffic on the Grand River is expected to remain essentially the same as at the present time except that larger barges and tugs and more barges per tow would undoubtedly be used if channel improvements were made. There is little possibility in the foreseeable future of a need for deep-draft commercial traffic on the Grand River upstream of Grand Haven Harbor.

24. EXISTING RECREATIONAL

Little information concerning existing recreational boating traffic on the Grand River is available. An inventory of existing docking facilities at Grand Haven and Spring Lake was conducted in 1965 by the Michigan State Waterways Commission. The number of seasonal berths available at commercial marinas, classified according to the length of craft, are shown in Table 14. In addition, there are a number of berths which are usually held open for the accommodations of transient craft.

Table 14

Seasonal Berths at Grand Haven and Spring Lake

Length of Craft	Number of Berths
Under 20 feet	164
20 feet - 29 feet	170
30 feet - 39 feet	60
40 feet and over	111

25. Some boating statistics are also available pertaining to bridge openings of the Spring Lake to Ferrysburg Bridge which crosses over the Federal project channel. These are shown in Table 15.

Table 15

Spring Lake - Ferrysburg Bridge Openings

	Type of Craft			
Year	Cruisers	Sailboats	Commercial	Total
1958	2,347	140	250	2,737
1959	2,505	116	254	2,876
1960	3,911	202	352	4,465
1961	3,488	257	303	4,048
1962	4,381	344	356	5,081
1963	*	261	470	*
1964	*	*	*	9,111

* Not available.

26. There are no statistics available on recreational boating for any upstream portion of the Grand River. However, it is known that there are significant numbers of recreational boaters who make use of the river, especially the improved reach downstream of the Bass River to Grand Haven. The unimproved sections of the river are used mainly by small local craft, mostly outboards, whose operators are familiar with the local hazards to navigation. Some indication of the number of boats which could use the Grand River can be gained from a study of the number of boats registered with the State of Michigan in those counties through which the Grand River flows. The total registered craft by county as of 31 December 1965, tabulated according to type and length, is shown in Table 16.

Table 16

Registered Small Craft by County - 1965

County	Type	Length: 12' and under	12'-20'	20'-30'	30'-40'	40' and over	Total
Ottawa	Outboard	1,035	4,157	73	2	1	5,268
	Inboard	8	299	200	29	6	542
	Sailboat	4	35	18	5	1	63
	Total	1,047	4,491	291	36	8	5,873
Kent	Outboard	4,846	14,589	307	11	2	19,755
	Inboard	32	514	315	85	18	964
	Sailboat	12	66	34	15	5	132
	Total	4,890	15,169	656	111	25	20,851
Ionia	Outboard	683	1,775	31	0	0	2,489
	Inboard	9	26	9	4	2	50
	Sailboat	1	0	2	0	0	3
	Total	693	1,801	42	4	2	2,542
Clinton	Outboard	484	1,680	21	0	0	2,185
	Inboard	6	25	7	3	1	42
	Sailboat	0	2	0	0	0	2
	Total	490	1,707	28	3	1	2,229
Eaton	Outboard	780	2,328	52	0	0	3,160
	Inboard	5	50	11	4	1	71
	Sailboat	1	4	0	1	0	6
	Total	786	2,382	63	5	1	3,237
Ingham	Outboard	2,908	8,916	173	3	1	12,001
	Inboard	19	248	105	37	6	415
	Sailboat	9	36	10	5	0	60
	Total	2,936	9,200	288	45	7	12,476
Jackson	Outboard	2,475	6,746	272	1	1	9,495
	Inboard	23	191	31	9	1	255
	Sailboat	6	19	3	4	0	32
	Total	2,504	6,956	306	14	2	9,782

27. PROSPECTIVE RECREATIONAL

Recreational boating's rise to popularity has been rapid. In 1958, the year the State first began registering boats, there were 217,553 craft in Michigan. By 1965, Michigan's boating population was about 400,000. These figures point out the tremendous growth in the popularity of recreational boating which has occurred in only a few years time. That this rapid growth will continue in the future is an opinion shared by all agencies, organizations, and persons concerned with the future of recreational boating.

28. The optimistic future predicted for recreational boating is based not only on past growth statistics but on increasing future population projections, rising national prosperity which provides the consumer with more money to spend on recreational pursuits, and the trend toward shorter workweeks and more holidays which allows more free time to devote to boating activities. Experience has shown that river and harbor improvements or the construction of new facilities results in an increase in the number of locally-based and transient boats. Another factor which has contributed to over-crowding and congestion at existing river and harbor improvements is the rapid increase in the number of trailer-drawn craft being used. These craft, usually 16 to 22 feet long, have no home port but are generally stored on land at the owner's home or any other accessible location and transported to and from the harbors and waterways on trailers. They include the popular deckless or semi-deckless out-board-driven craft used in calm weather for short duration cruises and the larger, cruiser-like, outboard-driven craft equipped with a for-ward cabin and used for longer duration cruises.

29. Future growth of recreational boating on the Grand River would be severely restricted under existing channel conditions. The Grand River is shoaled and unimproved upstream of the upper limit of the existing Federal project at the Bass River. There are no aids to navigation and the numerous bars, snags and other hazards to naviga-tion make the river dangerous even for local boaters familiar with local river conditions. However, if the river were improved, there is little doubt that it would be used extensively by locally-based transient, and trailer-drawn craft. The highly populated Grand Rapids and Lansing areas provide the demand and support for recrea-tional boating facilities and also serve as an attractive destination for craft cruising on Lake Michigan, especially those originating from the Chicago Metropolitan Area. Some indication of the potential use that an improved Grand River might receive is shown in Table 17. This is a forecast of the number of craft expected to be registered in those counties through which the Grand River passes, by the year 1980. These figures show an average increase of 100 percent over the

present registration figures as shown in Table 16. These statistics were taken from a published report entitled "Transportation Predictive Procedures - Recreational Boating and Commercial Shipping" prepared by the Waterways Division, Department of Conservation, of the State of Michigan. That report assesses and forecasts the nature and volume of existing and prospective waterborne vessel traffic in the State of Michigan.

Table 17

1980 Forecast of Registered Craft by County

County	Number of Craft
Ottawa	12,333
Kent	40,868
Ionia	4,728
Clinton	4,725
Eaton	6,765
Ingham	26,075
Jackson	17,998

SECTION X
RECOMMENDED SINGLE-PURPOSE IMPROVEMENTS

30. COMMERCIAL - GRAND HAVEN HARBOR

Information furnished by local interests and preliminary investigations by the Corps suggests that justification of harbor improvements at Grand Haven may be warranted, pending the results of engineering and economic feasibility studies. Existing harbor facilities, with the limiting project depth and a restricted turning basin, preclude the realization of a savings on transportation costs. If the deep draft improvements are instituted, as described under "Improvements Desired", paragraph 7, the vessels calling at the Port of Grand Haven could load to capacity, resulting in a savings due to faster loading and a decreased cost per ton. Information supplied by local commercial interests, and detailed in tables 18 and 19 show the economic advantages of increased harbor depth. Table 18 projects the economy of faster loading in 1968, 1973, and 1978 based on 1967 tonnages. In addition to a savings per vessel, harbor terminal facilities will be able to handle more vessels per season. Advantages of deeper harbor and channel facilities allowing deeper draft vessels and increased loading capacity is shown in table 19. Steamship companies queried by local interests suggest that an average freight savings of 5% on sand and gravel cargo revenue for each extra foot of draft below 21 feet to which the vessel can load will accrue with the deepening of the harbor.

31. Preliminary investigations suggest that the proposed harbor improvements appear justified. They will be further investigated under the existing authorized study adopted 1 March 1950 by the House Public Works Committee and discussed under "Additional Studies Authorized", in paragraph 5.

Table 18

Economic Savings in Freight Costs
As a Result of Faster Loading *
Based on 1967 Tonnage

(1) Deeper water will allow approximately one hour in time savings during loading for all vessels.

Vessels loaded in 1967	106
Deep-draft barges loaded in 1967	4
Total deep-draft vessels loaded	110
Total hours that could have been saved	110

Economic savings at $300 per hour based on 1967 tonnage . . . $33,000

Economic savings at $300 per hour based on projected tonnage
and 10,000 tons average per boat for 1968 . . . . $37,000
and 15,000 tons average per boat for 1973 . . . . $34,800
for 1978 . . . . $36,900

(2) An increase in loading capacity in tons per hour will result in a definite economic time saving for the vessels involved.

(a) Foundry sand loaded out 1967 616,490 net tons

Total loading time 1967 336 hours

Average tons per hour loaded 1,835

Total loading time based on 3000-3500 tons per hour 193 hours

Total hours in loading time to be saved @ 3250 tons per hour based on 1967 tonnage 143 hours

Economic savings based on 1967 tonnage $42,900

(b) Total hours in loading time to be saved based on 1968 projected tonnage (745,000 net tons) 174 hours

Economic savings based on 1968 anticipated tonnage $52,200

(c) Total hours in loading time to be saved based on 1973 projected tonnage (1,500,000 net tons) 355 hours

Economic savings based on 1973 anticipated tonnage. . . . $106,500

(d) Total hours in loading time to be saved based on 1978 projected tonnage (1,600,000 net tons) 380 hours

Economic savings based on 1978 anticipated tonnage $114,000

* Supplied by local interests.

Table 19

Local Sand and Gravel Concern
Anticipated Savings in Costs as a Result of
Deepening the Grand Haven Harbor to 25 Feet

Port	Allowable Draft	Anticipated Tonnage 1968	Anticipated Freight Cost 1968	% Saving	Anticipated Total Saving	Anticipated Tonnage 1973	Anticipated Freight @ 1968 Rate	% Saving	Anticipated Total Saving	Anticipated Tonnage 1978	Anticipated Freight @ 1968 Rate	% Saving	Anticipated Total Saving
Shipments:													
Buffalo	21-23	60,000	$136,800	5	$ 6,840	200,000	$456,000	5	$ 22,800	210,000	$478,800	5	$ 23,940
Cleveland	23	325,000	438,750	10	43,875	350,000	472,500	10	47,250	360,000	486,000	10	48,600
	27	0				250,000	337,500	20	67,500	260,000	351,000	20	70,200
Detroit	27	0				30,000	33,300	20	6,660	40,000	44,400	20	8,880
Hamilton, Ontario	25	75,000	150,000	20	30,000	90,000	180,000	20	36,000	100,000	200,000	20	40,000
Lorain, Ohio	23	10,000	11,500	10	1,150	0		10		0		10	
Port Weller	25	90,000	167,400	20	33,480	110,000	204,600	20	40,800	120,000	223,200	20	44,640
Sarnia, Ontario	22	60,000	66,600	5	3,330	100,000	111,000	5	5,550	100,000	111,000	5	5,550
Sombra, Ontario	22	20,000	22,200	5	1,110	0		5		0			
Windsor, Ontario	24	135,000	149,850	15	22,478	150,000	166,500	15	24,975	160,000	177,600	15	26,640
Receipts:													
Port Inland	25	60,000	60,000	20	12,000	75,000	75,000	20	15,000	95,000	95,000	20	19,000
					$154,263				$266,535				$287,450
Time Savings in Loading @ 1 Hour per Boat					37,000				34,800				36,900
Time Savings for Foundry Sand with New Loading Facility					52,200				106,500				114,000
Other Savings:													
According to a) Columbia Steamship Co.					20,000				25,000				30,000
b) Gartland Steamship Co.					4,200				5,250				4,620
TOTAL SAVINGS					$267,663				$438,085				$472,970

32. COMMERCIAL - GRAND RIVER

Based on the limited information available, widening the existing channel, especially at the bends, and increasing the project depth to 10 feet, from Grand Haven to the upstream project limit at the Bass River appears to be worthy of further detailed investigation. This channel is used by two sand and gravel companies who ship their raw materials by barge from their workings near the Bass River down to Grand Haven. At the present time, the tows consist of two barges and a push tug which make three round trips per day, six days per week. The sixth day is an overtime day necessitated by the fact that the size of the tows is limited by the present channel width. The operators desired to increase the size of the tows by utilizing three barges per tow instead of two. However, this cannot be done under existing channel dimensions, except during periods of high water when the longer tow would be able to extend out beyond the channel lines without danger of grounding. If the channel is widened to permit use of three barge tows at all times, a total of only 12 tows per week would be required to move the present commerce instead of the 18 tows per week now required. Therefore, the resultant benefit would be six less tows per week which would eliminate Saturday overtime and three other tows per week. The commercial users of the river estimate that should the channel be widened so that the described benefit be realized, a total economic savings of about $298,480 per year could be reasonably predicated. Widening the channel might also provide some benefit to recreational boating by increasing the safety to navigation in this reach of the river which is heavily used by commercial interests.

33. Widening the river channel from the present 100 foot width to 125 feet in the straight sections and 150 feet at the bends would be sufficient to permit use of three barge tows at all times. Increased usable channel widths of the Grand River above the railroad bridge are considered necessary to decrease the hazards and restrictions imposed on existing barge traffic and to afford the passage of longer tows in the future. The maneuvering characteristics and related space requirements of the existing and foreseeably longer tows determine the necessary widening.

34. Deepening of the existing project channel to 10 feet appears warranted inasmuch as the present 8-foot depth precludes the realization of more economical transportation rates available from deeper draft barges. Table 20 details transportation savings on sand and gravel shipments between Bass River and Spring Lake. Cost estimates assume a 125-foot channel width and show the savings on 8, 9, and 10-foot project depths. The cheapest transport cost per ton is realized with a 10-foot deep channel, allowing deeper draft barges and a cost per ton of $0.14. Cost estimates for engineering feasibility and derivable benefits are being made. The project merits further study. There is also no known potential user for a channel for deep-draft commerce on the Grand River upstream of Grand Haven.

Table 20

Savings on Sand Transported on Grand River Between Bass River and Spring Lake

	No Improvement	(total commerce 3,980,000 tons) Improvement - 125-foot channel and project depth		
		8-foot	9-foot	10-foot
Vessel operation cost per hour	$ 61	$ 61	$ 61	$ 61
Vessel time charged to cargo trip, hours	11	11	11	11
Cost per trip	671	671	671	671
Weighted average cargo per barge, tons	1,200	1,200	1,400	1,600
Number of barges per tow	3	3	3	3
Total cargo per tow	2,400	3,600	4,200	4,800
Trans. cost per ton	0.28	0.19	0.16	0.14
TOTAL COST	$1,114,400	$756,200	$636,800	$557,200
Annual transportation savings		$358,200	$477,600	$557,200
Savings per ton		0.090	0.120	0.140
Present worth of annual transportation savings				
1,180,000 @ Savings/ton		$106,200	$141,600	$165,200
2,800,000 @ Savings/ton x 0.34 (growth pattern factor)		$ 85,680	$114,240	$133,280
TOTAL		$191,880	$255,840	$298,480

35. <u>RECREATIONAL - BASS RIVER TO GRAND RAPIDS</u>

The reach of the Grand River extending from Grand Haven to the Bass River, and now covered by the present Federal project, is adequate for existing and prospective recreational boat traffic. The river upstream of the Bass River extending to Grand Rapids was formerly a part of the Federal project, but was abandoned by the 1930 River and Harbor Act. No work has been done on this reach of the Grand River since 1910 when a project providing for a 6-foot deep channel 100 feet wide was completed to Grand Rapids. This project involved the dredging of about 2,800,000 cubic yards of material and the construction of 132,624 linear feet of brush and pile training walls to confine the flow. In the absence of any commercial use of the upper river, the dredged channel above Bass River was not maintained and filled up so that by 1914 the low water depth was as little as 2-1/2 feet in places. It was estimated in 1932 that controlling depths at low water were probably less than 2 feet. The bed of the river in this reach is practically all sand and fine gravel, with clay found at a few points at depths of 10 to 15 feet. The channel width at low water is from 280 to 820 feet, which was narrowed by training walls to 160 to 180 feet in places. The training walls are for the most part washed out or buried in sand bars.

36. Preliminary estimates, based on available data, indicates that to provide a channel 5 feet deep and 100 feet wide from the Bass River to Grand Rapids, a distance of about 23 miles, in the interest of recreational navigation would require the excavation of about 1,800,000 cubic yards of material. The total first cost of such a project would amount to about $2,500,000. The average annual maintenance cost is estimated at about $60,000, based on previous experience gained in connection with the existing Federal project on the Grand River between Grand Haven and Bass River. The total annual charges, including cost of maintenance, would amount to approximately $160,000.

37. In order to economically justify such an expenditure of funds, the number of boats using the improved channel would have to amount to at least 400 locally-based craft and 4,000 transient boats annually. It is considered reasonable to expect that traffic of at least this magnitude would develop should the channel to Grand Rapids be improved. Channel width and depth was determined by the navigational requirements of a cruiser up to 65 feet in length. As these requirements are greater than those of smaller craft, they automatically provide for the adequate navigational needs of smaller craft. It is expected that many of the vessels on the Grand River will be inboards and cruisers in the 17 to 40 feet long class. However, the river is sufficiently wide, with many tributaries and coves, such that joint use of the river by power boat enthusiasts, sailors,

canoeists, and fishermen, may be pursued with recreational enjoyment by all without interference. This joint use provides maximum recreational advantages and is an important part of project justification. Some of the factors which indicate that this channel improvement may be economically feasible are the present popularity of recreational boating and the expected continuation of this trend, the heavily populated Grand Rapids area which provides a market for prospective boat purchasers and a destination for transient boaters, the relative lack of boating facilities in the Grand Rapids Area, and access to Lake Michigan and its heavily traveled coastline especially for craft originating in the Chicago Metropolitan Area. The minimum vertical clearance under high water conditions for any of the fixed bridges in this section of the river is 15 feet which will allow passage of almost any cruiser type vessel.

38. RECREATIONAL - UPSTREAM OF GRAND RAPIDS

An investigation was made as to the economic feasibility of providing an improved channel for recreational boating upstream of Grand Rapids. The plan investigated was that suggested by the Waterways Division of the Department of Natural Resources, State of Michigan, comprising a lock at Grand Rapids, a channel 80 feet wide and 5 feet deep to Lowell, and a channel 50 feet wide and 4 feet deep to the dam at Lyons. This covers a river distance of about 55 miles and passes under 17 bridges mostly at Grand Rapids and the principal towns along the route. In order to provide a through channel, a lock must be constructed at the Grand Rapids dam where the difference in water elevation is 18 feet. Upstream of Grand Rapids the river width varies from 100 to 1,950 feet with an average width of about 200 feet. Depths in this reach of the river vary considerably, but probably average about 2 feet under low water conditions. The river bed is composed almost entirely of sand and gravel and frequent bars obstruct the channel.

39. Preliminary estimates made to determine the cost of the suggested plan of improvement indicated that it would cost about 5 million dollars to provide for recreational navigation on the Grand River upstream of Grand Rapids. This includes the cost of a lock, but not for any bridge modifications that might be necessary. The total annual charges for such an improvement, including annual maintenance, would be about $400,000. To obtain annual benefits equal to the estimated annual charges would mean that at least 800 locally-based boats ranging in length from 17 to 65 feet would have to be based in this reach of the river and well over 10,000 transient craft visits would be required annually. There is no indication that such a volume of traffic would materialize in the near future should the considered improvement be constructed. Therefore, based on the limited information available, it is concluded that improvement of the Grand River upstream of

Grand Rapids is not economically justified at this time. Should the future demand far exceed that which can be reasonably foreseen at the present time, the subject of an improved navigation channel upstream of Grand Rapids can be studied again at such time.

40. The Lyons dam is the first of a series of four dams over a 14-mile reach of river extending from Lyons to Portland. Water depths of up to 30 feet exist in some of the pools upstream of the dams. Providing a channel 50 feet wide and 4 feet deep between the dam sites, to accommodate trailer-drawn craft and small boats which can be portaged around the dams, involves the removal of shoals and bars and is primarily a clearing and snagging type project. This work also cannot be economically justified in itself since the number of craft needed to make such an improvement feasible cannot be reasonably anticipated in the near future. This improvement could also be restudied along with the reach between Grand Rapids and the Lyons dam should future conditions change sufficiently to justify such action. Impoundments of the Grand River or its tributaries between Portland and Lansing and between Lansing and Jackson to provide lakes for recreational boating could best be realized by the construction of reservoirs justified on a multi-purpose basis rather than through single-purpose navigation projects.

SECTION XI
CONCLUSIONS

41. The existing and future utilization of the Grand River in the interest of recreational and commercial navigation is being investigated. Studies include an analysis of existing navigation projects and their relationship to present and prospective commerce and vessel traffic, and investigations to determine the desirability of modifying existing projects or providing additional improvements for both commercial and recreational navigation. It is concluded, based on the limited information available, that further improvement of Grand Haven Harbor and the lower reach of the Grand River to the Bass River for commercial navigation and improvement of the Grand River up to Grand Rapids for recreational navigation appear to have some economic justification and be worthy of further detailed study. Detailed study of the commercial improvements is presently underway in accordance with a study authorized by a House Public Works Committee Resolution adopted 1 March 1950. There is also another study authorized by a House Public Works Committee Resolution adopted 9 April 1957 which will cover the recreational boating aspect of navigation on the Grand River. These two authorized studies are expected to adequately provide the further detailed study recommended by this appendix. In summary, the following improvements appear at this time, subject to further study, to exhibit economic feasibility.

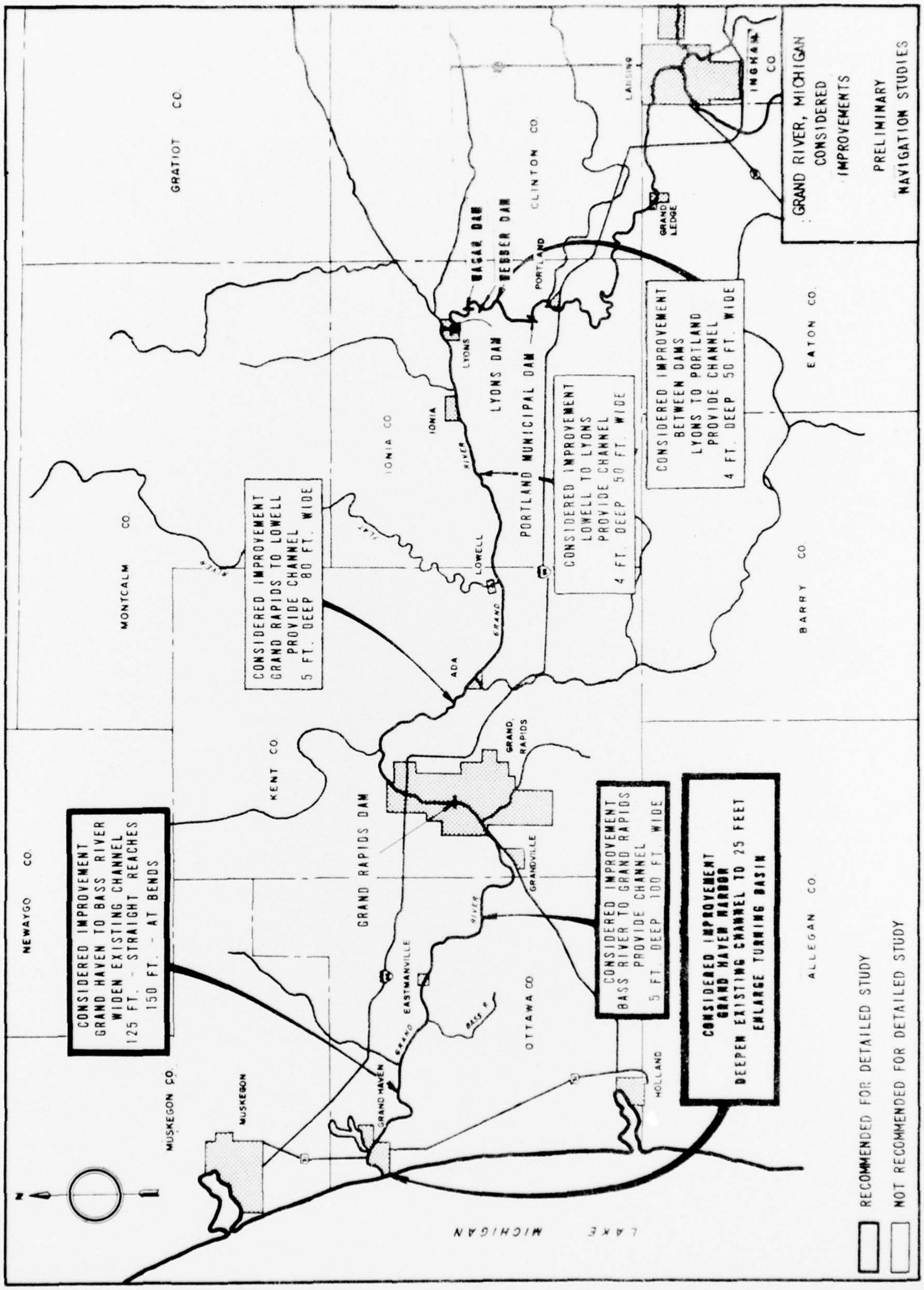
a. Improving Grand Haven Harbor in the interest of commercial navigation by deepening the existing channel to provide a controlling depth of 25 feet and enlarging the turning basin.

b. Improving the Grand River channel from Grand Haven to the Bass River in the interest of commercial navigation by widening the existing project channel to 125 feet in the straight reaches and 150 feet at the bends, and possibly increasing the project depth.

c. Improving the Grand River in the interest of recreational navigation from the Bass River to Grand Rapids, a distance of about 23 miles, by providing a channel 5 feet deep and 100 feet wide.

Improvements for recreational boating upstream of Grand Rapids were investigated, but were determined to be not economically feasible at this time. However, this does not preclude further study of these improvements should the need arise at some future date.

The detailed studies recommended by this report will identify the most suitable methods and areas for disposal of the spoil from the initial dredging of the channel and from maintenance dredging.



GRAND RIVER, MICHIGAN
CONSIDERED IMPROVEMENTS
PRELIMINARY NAVIGATION STUDIES
CONSIDERED IMPROVEMENT
GRAND HAVEN TO BASS RIVER
WIDEN EXISTING CHANNEL
125 FT. - STRAIGHT REACHES
150 FT. - AT BENDS
CONSIDERED IMPROVEMENT
BASS RIVER TO GRAND RAPIDS
PROVIDE CHANNEL
5 FT. DEEP 100 FT. WIDE
CONSIDERED IMPROVEMENT
GRAND HAVEN HARBOR
DEEPEN EXISTING CHANNEL TO 25 FEET
ENLARGE TURNING BASIN
CONSIDERED IMPROVEMENT
GRAND RAPIDS TO LOWELL
PROVIDE CHANNEL
5 FT. DEEP 80 FT. WIDE
CONSIDERED IMPROVEMENT
LOWELL TO LYONS
PROVIDE CHANNEL
4 FT. DEEP 50 FT. WIDE
CONSIDERED IMPROVEMENT
BETWEEN DAMS
LYONS TO PORTLAND
PROVIDE CHANNEL
4 FT. DEEP 50 FT. WIDE
GRAND RAPIDS DAM
PORTLAND MUNICIPAL DAM
LYONS DAM
WAGAR DAM
WEBBER DAM
MUSKEGON CO.
NEWAYGO CO.
KENT CO.
MONTCALM CO.
GRATIOT CO.
IONIA CO.
CLINTON CO.
INGHAM CO.
EATON CO.
BARRY CO.
ALLEGAN CO.
OTTAWA CO.
LAKE MICHIGAN
MUSKEGON
GRAND HAVEN
EASTMANVILLE
GRANDVILLE
GRAND RAPIDS
HOLLAND
ADA
LOWELL
IONIA
LYONS
PORTLAND
GRAND LEDGE
LANSING
GRAND RIVER
BASS R.
FLAT RIVER
N
RECOMMENDED FOR DETAILED STUDY
NOT RECOMMENDED FOR DETAILED STUDY

PLATE I-3

ATTACHMENT A, APPENDIX I

NAVIGATION REPORTS ON THE
ORIGINAL GRAND HAVEN HARBOR PROJECT

ATTACHMENT A

TO

APPENDIX I - NAVIGATION

REPORTS ON THE ORIGINAL GRAND HAVEN HARBOR PROJECT

1. A survey report dated 15 December 1849 published as Senate Ex. Document No. 20, 31st Congress, 1st Session, considered the advisability of improving Grand Haven Harbor for the benefit of general lake commerce. The reports' recommendations were generally adopted by the River and Harbor Act of 23 June 1866 which established the original Grand Haven Project. The original project provided for a 18-foot deep channel by means of parallel piers 400-feet apart projecting into Lake Michigan, and shore and channel revetments on both banks of the mouth of the Grand River.

2. The report dated 3 February 1880, published as Senate Ex. Document No. 92, 46th Congress, 2nd Session, recommended that the piers be extended to terminate in water having an 18-foot depth and that the beach be stabilized to prevent the drift of sand into the project area. The recommendations were adopted by the River and Harbor Act of 1880.

3. A special report dated 18 January 1890, published as Senate Ex. Document No. 40, 51st Congress, 1st Session, indicated that although waterborne commerce had benefited from construction of piers and revetments, construction of these structures to their authorized length should be accomplished as soon as practicable in order that the harbor's full commercial potential may be realized.

4. The reports of a preliminary examination and a survey, dated 31 May 1909 and 30 December 1910, were published in House Doc. No. 282, 63rd Cong., 1st Sess. Although the preliminary examination was favorable, the survey concluded that it was not advisable at that time to continue the project to Fulton Street in Grand Rapids or to include a channel into Spring Lake.

5. A preliminary examination report dated 31 January 1921 was also unfavorable to modification of the project.

6. The reports of a preliminary examination and survey, dated 8 October 1925 and 6 December 1927, were favorable to modification of both the harbor and river projects. These reports were printed in House Document No. 103, 70th Congress, 1st Session. It was recommended that the harbor project be modified to provide a 22-foot deep and 300-foot wide entrance channel from Lake Michigan

to a point 1,000 feet inside the pier ends, then 20 feet deep to the Grand Trunk Railway car-ferry slip, with a turning basin. The modifications recommended for the river project are included in the reports on the original river project, par. 21, below.

7. The recommendations contained in the above House Document were reviewed and modified in survey report dated 5 February 1929. The Board of Engineers for River and Harbors, by report dated 4 February 1930, concurred with the recommendations of the review report. It was recommended that the Grand Haven project be modified to provide a channel 23 feet deep and generally 300 feet wide from Lake Michigan to a point 1,000 feet inside the pier ends; then 21 feet deep and 300 feet wide to the car-ferry slip, with an enlargement at the upper end. Also that the Grand Haven Harbor and Grand River projects be combined. These recommendations were published in Senate Document No. 88, 71st Congress, 2nd Session, and adopted by the River and Harbor Act of 3 July 1930.

SECTION II
REPORTS ON THE ORIGINAL GRAND RIVER PROJECT

8. The first examination and survey of the Grand River upstream to Grand Rapids was authorized by the River and Harbor Act of 1880. A report by the Detroit Engineer Office, dated 12 February 1881, published as Senate Ex. Document No. 50, 46th Congress, 3rd Session, indicated the city of Grand Rapids could prosper by being opended to general lake commerce. It also indicated an adequate ship channel, preferably 10 feet deep and 100 feet wide, could be constructed either entirely or partially within the banks of the river. The work, which in effect would be similar to the construction of a canal, would require careful and complete site examinations to determine the most economical alignment. The report concluded that existing light-draft navigation, then consisting of a single steamboat drawing not more than 2-1/2 feet loaded, could more adequately handle the river commerce if a 4 feet deep channel could be provided. The estimated cost of a 100-foot wide channel from Grand Rapids downstream to deep water was $25,000. The 4-foot deep channel was adopted by the River and Harbor Act of 1881. The acts of 1881 and 1882 appropriated $10,000 and $15,000, respectively, for dredging the 4-foot channel. By July 1884, 2-1/2 miles had been completed. The act of 1885 appropriated an additional $25,000. By July 1886, a 60-foot wide and 4-1/2 foot deep channel had been dredged 11-1/4 miles below Grand Rapids. The dredged channel was not considered permanent and further appropriations were not recommended.

9. A preliminary examination report dated 29 January 1887 concluded, in view of the extreme range between high and low water stages and the shoaling tendency of the river bottom material, that a deep-water connection from Lake Michigan to Grand Rapids could not be accomplished entirely within the banks of the river. Such a connnection would require the construction of a canal outside of the river banks, but would utilize the river water.

10. Another preliminary examination report, dated 25 October 1888, considered the advisability of providing a 10-foot deep channel from Grand Rapids to Lake Michigan. This report also considered it impracticable to dredge the river to provide the channel as there was insufficient flow at low water stage and construction of locks and dams would require expensive levee construction. It concluded that a canal outside of the river banks would be the most economical means of providing a deep-water connection and that its depth should be at least 14 feet in view of the tendency toward the use of lake vessels with greater drafts.

11. A special report, dated 22 March 1890, by the Detroit Engineer Office summarized the 10-year history of the study and improvement of the Grand River below Grand Rapids. The report concluded that a more thorough investigation of the river, at an estimated cost of $8,000, should be completed in order to provide more detailed information on which to determine the most practical means of providing further improvement in the interest of commercial navigation. The Board of Engineers for Rivers and Harbors, in a report dated 12 April 1890, concurred with the special report. The Board's report cited a recent survey of the river, completed at the expense of the city of Grand Rapids, that had added materially to the topographical information available, and that further hydraulic, subsurface and topographic data would be required. It indicated the river could possibly be deepened to 10 feet, although the use of a lock and movable dam might be more economical.

12. The Detroit Engineer Office's preliminary examination report dated 12 November 1890 reduced the previously estimated cost of accomplishing a thorough investigation of the river below Grand Rapids in view of the survey information furnished by the city of Grand Rapids.

13. Another survey report, dated 11 April 1892 and based on a thorough investigation of the Grand River below Grand Rapids, recommended the construction of a 10-foot navigable channel downstream from the city. The estimated costs of the three improvements considered, all within the banks of the river are:

(1) For the open 8-foot navigation-------------------$463,450

(2) For 10-foot navigation with lock and dam----------673,880

(3) For the open 10-foot navigation-------------------670,500

The report was published as House Ex. Document No. 197, 52nd Congress, 1st Session.

14. The River and Harbor Act of 3 June 1896 authorized construction of the 10-foot deep channel, 90 to 100 feet wide, through the bars of the river, as recommended by the above 1892 survey report. The act of 13 June 1902 extended the upstream terminus of the project about 3,200 feet further to Fulton Street in Grand Rapids. In response to a resolution by the Committee on Rivers and Harbors of the House of Representatives, the Board of Engineers for Rivers and Harbors prepared a report, dated 11 November 1903, that estimated the project would cost more than one million dollars to complete. The Board indicated the project, if completed, would be inadequate for lake vessels; that the cost of a channel for lake vessels would be out of proportion to the general benefits it would afford; and that it was more practical to provide a 6-foot deep channel that would benefit commerce practically as much as a 10-foot channel. It recommended the project be modified to provide a 6-foot deep channel, 100 feet wide, downstream from Fulton Street. It was estimated that the modified project would cost $430,000, of which $103,000 was then available from previous appropriations. The estimate was based on the supposition that the additional $327,000 would be available within one year. The River and Harbor Act of 3 March 1905 modified the project to provide a 6-foot depth below low water of 1889 and appropriated $100,000, none of which was to be used to provide a turning basin within the city of Grand Rapids.

15. Exceptionally high floods occurred on the Grand River in 1904 and 1905 and caused extensive damage to the Grand Rapids area. The River and Harbor Act of 2 March 1907 authorized an examination of the river with a view to the regulation of floods in the interest of navigation. A special board of engineer officers inspected the Grand River below Grand Rapids, held a public hearing and, after reviewing all available information and data, prepared a report dated 29 May 1907. The report, published as House Document No. 72, 60th Congress, 1st Session, concluded that the regulation of floods is not required in the interest of navigation and that protection against flood damage is a matter for local determination.

16. A brief report by the District Engineer Office, dated 27 September 1909, discussed the causes that led to the decline of waterborne commerce on the Grand River. The report cited the lack of available freight, due

to the closing of sawmills along the river and the construction of convenient railroad facilities to every factory, mill and gypsum mine in the area, as the primary cause for ending the forty-year old light-draft steamboat service in 1893. Construction of the 6-foot deep channel greatly improved water transportation but it was coincident with the new competition of electric railway lines that provided more economical, reliable, rapid and convenient passenger land freight service to Grand Haven, Muskegon and Holland.

17. A special report dated 6 May 1912 indicated that only the lower portion of the Grand River, from Grand Haven to the mouth of the Bass River, or to Lamont if sufficient use is made of the channel, should be maintained by dredging.

18. Another brief report dated 5 February 1913 surveyed the terminal and transfer facilities contiguous to waters under improvement by the United States. It indicated there were no such commercial facilities along the river in Grand Rapids; that none were planned to encourage prospective waterborne commerce; that the terminal for the previously operated steamboat service had been obliterated; and that floodwalls or embankments line the river banks within the city.

19. A preliminary examination report dated 20 May 1914, published as House Document No. 1146, 63rd Congress, 2nd Session, considered the advisability of modifying the project to provide a 15-foot deep channel downstream from Grand Rapids to Lake Michigan in lieu of the 6-foot authorized. The report concluded, after consideration of the small amount of light-draft commerce between Grand Haven and Lamont; the absence of river commerce above Lamont; the inadequacy of a 15-foot deep channel with the greater draft of lake vessels; the general lack of interest by business and unforeseeable potential commerce; and the adequacy of rail service, that the deepened channel is not warranted in the interest of navigation. It also concluded that should local interests desire to construct a deeper and wider channel for improvement of flood conditions and water power, they should be allowed to remove existing Government dikes as might be necessary.

20. A preliminary examination report dated 27 November 1915, published as House Document No. 667, 64th Congress, 1st Session, indicated there was practically no river commerce above Lamont and recommended that this reach of the project be abandoned.

21. A preliminary examination, dated 8 October 1925, and a survey report dated 6 December 1926, both published in House Document No. 103, 70th Congress, 1st Session, recommended the modification of the harbor and river projects. It was recommended that the river project be modified to provide for a channel 20 feet deep and 200 feet wide, from

the Grand Trunk Railway car-ferry slip, the upstream limit of the Grand Haven Harbor project, to the Grand Trunk Railway bridge at Ferrysburg, then 8 feet deep and 100 feet wide to the mouth of the Bass River, provided that local interests contribute 50 percent of the actual cost of this dredging. It was also recommended that the reach of the Grand River above the mouth of the Bass River be eliminated from the project. The recommended harbor modifications were previously described in paragraph 6.

22. The above recommendations were reviewed and modified in a survey report dated 5 December 1929. The Board of Engineers for Rivers and Harbors concurred with the review survey's recommendations on 4 February 1930 that it was advisable to modify the river project to provide a 21-foot deep and 300-foot wide channel between the Grand Trunk Railway car-ferry slip and its bridge at Ferrysburg, and an 8-foot deep and 100-foot wide channel upstream of the bridge to the Bass River, provided local interests contribute suitable areas for spoil materials. Combining the river and harbor projects was also recommended. These modified recommendations, published in Senate Document No. 88, 71st Congress, 2nd Session, were adopted by the River and Harbor Act of 3 July 1930.

SECTION III
REPORTS ON THE COMBINED GRAND HAVEN HARBOR AND GRAND RIVER PROJECT

23. A preliminary examination report dated 3 August 1932 prepared under the provisions of House Doc. No. 308, 69th Congress and published as House Document No. 80, 73rd Congress, 1st Session, concluded that improvement of the Grand River for navigation or in combination with power development, flood control, or irrigation, was not advisable at that time.

24. A preliminary examination report dated 10 October 1932 concluded the construction of a breakwater at the harbor entrance was not advisable at that time.

25. A survey report dated 8 July 1935 considered it inadvisable to widen and deepen the channel reach between the car-ferry slip and the Grand Trunk Railway bridge; deepen the South Channel to the Third Street bridge; enlarge the existing turning basin; and provide another turning basin halfway between the existing one and the upper end of the project.

26. A review report contained in River and Harbor Committee Document No. 1, 75th Congress, 1st Sess., recommended a channel 18 feet deep and 100 feet wide from the head of the authorized 21-foot deep channel, at the Grand Trunk Railway bridge, into Spring Lake. This recommended channel was adopted by the River and Harbor Act of 26 August 1937.

27. A survey report dated 8 December 1939, published as House Document No. 661, 76th Congress, 3rd Session, reviewed the reports contained in House Document No. 103, 70th Congress, 1st Session. The review survey recommended modification of the project to provide for a channel 300 feet wide and 21 feet deep from the enlargement in the existing channel at the Grand Trunk Western car-ferry slip to and including an 18-foot deep turning basin at the Grand Trunk Western Railway bridge.